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U.S. Army Environmental Center

REMEDIAL INVESTIGATION/FEASIBILITY STUDY
BADGER ARMY AMMUNITION PLANT
BARABOO, WISCONSIN

FINAL
FEASIBILITY STUDY
DATA ITEM A009

VOLUME III OF III
APPENDICES

CONTRACT DAAA15-91-D-0008
U.S. ARMY ENVIRONMENTAL CENTER
ABERDEEN PROVING GROUND, MARYLAND

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AUGUST 1994

FINAL FEASIBILITY STUDY
BADGER ARMY AMMUNITION PLANT

LIST OF APPENDICES

APPENDIX A

SOIL CONTAMINANT MODELING

APPENDIX A.1

EXAMPLE CALCULATIONS - ORGANICS

PROJECT	COMP. BY	JOB NO.
EXAMPLE CALCULATIONS FOR DETERMINING PROTECTION OF GROUNDWATER PER NR 720	JSM	6853-09
	CHK. BY M. Stelmack	DATE 4/6/94

THE FOLLOWING CALCULATIONS DEMONSTRATE THE APPROACH USED BY ABB-ES FOR DETERMINING CONCENTRATIONS OF ORGANICS IN BAAP SOIL THAT ARE PROTECTIVE OF GROUNDWATER. FOR THIS EXAMPLE, 2,4-DINITROTOLUENE (24DNT) IN SUBSURFACE SOIL AT THE PROPELLANT BURNING GROUND (PBG) WASTE PITS IS MODELLED. PER THE ~~ATTACHED~~ JSM DESCRIPTION IN APPENDIX A.3 OF THE MODELING EFFORT, INITIAL SCREENING OF ORGANIC CONTAMINANTS WAS CONDUCTED USING THE ORGANIC LEACHING MODEL (OLM). PRIOR TO CALCULATING THE SOIL TARGET CONCENTRATION USING THE OLM, THE VALUE OF THE LEACHATE CONCENTRATION IN GROUNDWATER IS DETERMINED BY MULTIPLYING THE WPAL BY THE DILUTION ATTENUATION FACTOR (DAF). THE METHOD FOR CALCULATING THE DAF IS PROVIDED (AS CORRECTED) IN NR 720.

CALCULATIONS FOR DAF AT PBG WASTE PITS:

$$DAF = 1 + \frac{KId}{RL}$$

K = HYDRAULIC CONDUCTIVITY
= 4×10^{-2} CM/SEC (RI REPORT)
= 41,386 FT/YR

I = HYDRAULIC GRADIENT
= 0.0014 FT/FT (RI REPORT)

d = DEPTH OF GROUNDWATER MIXING ZONE
= 10 FEET (DEFAULT VALUE PER NR 720)

R = AVERAGE GROUNDWATER RECHARGE RATE
= 10 IN/YR (DEFAULT VALUE PER NR 720)

L = HORIZONTAL EXTENT OF CONTAMINATED SOIL PARALLEL TO THE HYDRAULIC GRADIENT
= 200 FEET (ESTIMATED DIAMETER [100'] OF 24DNT CONTAMINATION AT EACH WASTE PIT MULTIPLIED BY 2 WASTE PITS PARALLEL TO THE HYDRAULIC GRADIENT)

$$\Rightarrow DAF = 1 + \frac{(41,386\ FT/YR)(0.0014\ FT/FT)(10\ FT)}{(10/12\ \frac{FT}{YR})(200\ FT)}$$

$$DAF = 4.48$$

CALCULATION FOR LEACHATE CONCENTRATION IN GROUNDWATER:

C_L = WPAL × 4.48

$C_L = 0.005\ \mu g/l \times 4.48 = 0.0224\ \mu g/l$

FORM 00.01 REV. 4/81

ABB Environmental Services, Inc.

PROJECT	COMP. BY	JOB NO.
EXAMPLE CALCULATIONS	JSM	6853-09
	CHK. BY M. Stelmack	DATE 4/6/94

CALCULATE SOIL TARGET FOR 24DNT USING OLM:

$$C_l = 0.00221\,(S)^{0.373}\,(C_s)^{0.678}$$

C_l = CONCENTRATION OF LEACHATE
$= 0.0224\ \mu g/l = 2.24 \times 10^{-5}\ mg/l$

S = SOLUBILITY OF 24DNT IN WATER
$= 240\ mg/l$

C_s = SOIL TARGET CONCENTRATION

REARRANGING THE OLM EQUATION:

$$C_s = \left(\frac{C_L}{(0.00221)(S)^{0.373}}\right)^{1/0.678}$$

$$C_s = \left(\frac{2.24 \times 10^{-5}\ mg/l}{(0.00221)(240\ mg/l)^{0.373}}\right)^{1/0.678}$$

$$\underline{C_s = 5.6 \times 10^{-5}\ mg/kg}$$

BECAUSE SCREENING 24DNT WITH THE OLM INDICATES THAT THE SOIL TARGET CONCENTRATION (5.6×10^{-5} mg/kg) IS LESS THAN THE MAXIMUM 24 DNT CONCENTRATION ($\approx$ 280,000 mg/kg) IN SOIL, ADDITIONAL MODELING USING THE JURY MODEL WAS CONDUCTED TO ESTIMATE THE ATTENUATING EFFECTS OF PARTITIONING, VOLATILIZATION, AND DEGRADATION OF 24DNT. AT THE WASTE PITS, SOIL TARGET CONCENTRATIONS WERE COMPUTED USING THE JURY MODEL FOR 20-FOOT THICK ZONES IN THE SUBSURFACE SOIL COLUMN BELOW THE WASTE PITS. FOR THIS EXAMPLE, THE 0-20-FOOT BGS INTERVAL IS MODELLED. SEE THE ATTACHED JURY MODEL OUTPUT FOR THIS RUN FOR A SUMMARY OF MODEL INPUT PARAMETERS.

NOTE: WHILE THE JURY MODEL INPUT IS THE CONTAMINANT CONCENTRATION IN SOIL ($\mu g/g$), THE MODEL OUTPUT CALCULATES THE TOTAL MASS PER ELEMENTAL VOLUME OR $\mu g/cm^3$. THUS THE FINAL CONCENTRATION MUST BE RECONVERTED VIA A MASS BALANCE CALCULATION TO OBTAIN AN UNSATURATED ZONE ATTENUATION FACTOR (UZAF).

PROJECT	COMP. BY	JOB NO.
EXAMPLE CALCULATIONS	ISM	6853-09
	CHK BY M. Stelmack	DATE 4/6/94

THE MODEL OUTPUT CONSISTS OF 24DNT CONCENTRATIONS AS A FUNCTION OF TIME AND DEPTH. BECAUSE THE OBJECTIVE IS TO MODEL IMPACT ON GROUNDWATER, AND THE GROUNDWATER TABLE IS AT APPROXIMATELY 110 FEET BGS, THE DEPTH INTERVAL AT 3,350 CM (~110 FEET) IS OF INTEREST. FROM THE MODEL OUTPUT, IT CAN BE OBSERVED THAT THE MAXIMUM CONCENTRATION REACHING 3,350 CM BGS OVER TIME IS ESTIMATED TO BE 0.129 $\mu g/cm^3$.

THE JURY MODEL IS DERIVED FROM THE FOLLOWING EQUATION:

$$C_T = \rho_b C_s + \Theta C_\ell + a C_g$$

C_T = TOTAL CONCENTRATION IN $\mu g/cm^3$
C_s = CONCENTRATION IN THE ADSORBED PHASE
C_ℓ = CONCENTRATION IN THE DISSOLVED PHASE
C_g = CONCENTRATION IN THE GASEOUS PHASE

ASSUMING NO VOLATILIZATION OF 24DNT INTO THE GASEOUS PHASE, THE EQUATION CAN BE SIMPLIFIED TO:

$$C_T = \rho_B C_s + \Theta C_\ell$$

THE FOLLOWING LINEAR PARTITIONING MODEL CAN BE USED TO CONVERT THE EQUATION INTO A USEFUL FORM:

$$C_\ell = C_s / K_d$$

K_d = SOIL-WATER PARTITION COEFFICIENT
= $K_{oc} \cdot f_{oc}$

K_{oc} = ORGANIC CARBON PARTITION COEFFICIENT
= 45 $m\ell/g$ (cm^3/g) FOR 24DNT

f_{oc} = FRACTION ORGANIC CARBON IN SOIL
= 0.001 (CONSERVATIVE ESTIMATE)

$$\Rightarrow C_T = \rho_B C_s + \Theta C_s / K_{oc} \cdot f_{oc}$$

$$\Rightarrow C_s = \frac{C_T}{\left(\rho_B + \frac{\Theta}{K_{oc} \cdot f_{oc}}\right)}$$

ρ_B = SOIL BULK DENSITY
= 1.7 g/cm^3

Θ = SOIL VOLUMETRIC WATER CONTENT
= 0.05

$$\Rightarrow C_s = \frac{C_T}{\left(1.7 + \frac{0.05}{(0.001)(45)}\right)} = \frac{C_T}{2.81} \ \mu g/g$$

PROJECT	COMP. BY	JOB NO.
EXAMPLE CALCULATIONS	JSM	6853-09
	CHK. BY N. Stelmack	DATE 4/6/94

CALCULATE UZAF:

$$\frac{C_{so}}{C_{sf}} = \frac{100,000}{(0.129/2.81)}$$
$$\approx 2.18 \times 10^6$$

$$\Rightarrow \underline{UZAF \approx 2.18 \times 10^6}$$

THE NEXT STEP IS TO ESTIMATE THE SOIL TARGET CONCENTRATION AT THE WATER TABLE.

CALCULATE SOIL TARGET CONCENTRATION AT WATER TABLE:

C_s (WATER TABLE) = WPAL × DAF × K_d

WPAL = 0.005 μg/l
DAF = 4.48
K_d = 0.045 ml/g

$$\Rightarrow C_s \text{ (WATER TABLE)} = \frac{0.005\ \mu g}{1,000\ ml} \times 4.48 \times \frac{0.045\ ml}{g}$$
$$= 1.008 \times 10^{-6}\ \mu g/g$$

THE FINAL STEP IS TO CALCULATE THE SOIL TARGET CONCENTRATION AT THE 0-20 FOOT INTERVAL.

CALCULATE SOIL TARGET CONCENTRATION AT 0-20' BGS:

$$C_s(0\text{-}20'\text{ BGS}) = 1.008 \times 10^{-6}\ \mu g/g \times UZAF$$
$$= 1.008 \times 10^{-6}\ \mu g/g \times 2.18 \times 10^6$$
$$\approx \underline{2.2\ \mu g/g\ \text{(OR mg/kg)}}$$

NOTE: WITH INCREASING DEPTH, THE SOIL TARGET CONCENTRATION DECREASES IN PROPORTION TO THE DECREASE IN THE UZAF. THE REMEDIATION GOALS FOR ALL ORGANIC SUBSURFACE SOIL CONTAMINANTS ARE DERIVED FROM THE LOWEST UZAF.

PROJECT TITLE = Badger
JOB # = 6853-09
DATE = 3/29/94
NAME = R. Lewis

SOIL PROPERTIES
SOIL BULK DENSITY (G/CM3) = 1.7
SOIL VOLUMETRIC WATER CONTENT (DIM) = .05
SOIL VOLUMETRIC AIR CONTENT (DIM) = .3
TOTAL SOIL POROSITY (DIM) = .35
FRACTION OF ORGANIC CARBON (DIM) = .001

TRANSPORT PROPERTIES
AIR BOUNDARY LAYER THICKNESS (CM) = .5
INFILTRATION RATE (CM/DAY) = .0696

CHEMICAL DATA
CHEMICAL NAME = 24-DNT
INITIAL CONCENTRATION (PPM) = 100000
HENRY'S LAW CONSTANT (DIM) = .00022
ORGANIC CARBON PART COEF (CM3/G) = 45
HALF LIFE (DAYS) = 267
DEPTH TO TOP OF CONTAMINANTS (CM) = 0
THICKNESS OF CONTAMINANT ZONE (CM) = 610

CONCENTRATION(PPM) AS A FUNCTION OF TIME AND DEPTH

DEPTH(CM)	TIME(DAYS)				
	4500.0	4600.0	4700.0	4800.0	4900.0
3200.000	0.105	0.179	0.241	0.265	0.252
3250.000	0.041	0.089	0.148	0.193	0.209
3300.000	0.013	0.037	0.076	0.121	0.155
3350.000	0.003	0.012	0.032	0.064	0.099
3400.000	0.001	0.003	0.011	0.028	0.054

CONCENTRATION(PPM) AS A FUNCTION OF TIME AND DEPTH

DEPTH(CM)	TIME(DAYS) 5000.0	5100.0	5200.0	5300.0	5400.0
3200.000	0.216	0.174	0.136	0.105	0.080
3250.000	0.196	0.167	0.134	0.105	0.081
3300.000	0.165	0.153	0.129	0.104	0.081
3350.000	0.124	0.129	0.119	0.100	0.080
3400.000	0.081	0.099	0.102	0.093	0.077

FLUX (MICROGRAMS/CM*CM/DAY) AND LOSS (PERCENT)
AS A FUNCTION OF TIME

TIME(DAYS)	FLUX	LOSS
4500.0	0.000	0.1858
4600.0	0.000	0.1858
4700.0	0.000	0.1858
4800.0	0.000	0.1858
4900.0	0.000	0.1858
5000.0	0.000	0.1858
5100.0	0.000	0.1858
5200.0	0.000	0.1858
5300.0	0.000	0.1858
5400.0	0.000	0.1858

CAUTION: THE USE OF TOO LARGE TIME STEPS MAY CAUSE THE ESTIMATED CUMULATIVE VOLATILIZATION LOSSES TO BE ERRONEOUS. USE THE ESTIMATED TOTAL LOSSES AT INFINITE TIME AS FOLLOWS.

THE TOTAL FRACTION VOLATILIZED IS APPROXIMATELY 0.0339
ASSUMING ZERO WATER EVAPORATION AND LARGE KH (SEE JURY APP. B)

APPENDIX A.2

EXAMPLE CALCULATIONS - METALS

PROJECT	COMP. BY	JOB NO.
EXAMPLE CALCULATIONS FOR DETERMINING PROTECTION OF GROUNDWATER PER NR 720	JBM	6853-09
	CHK. BY M. Sledmick	DATE 4/6/94

THE FOLLOWING CALCULATIONS DEMONSTRATE THE APPROACH USED BY ABB-ES FOR DETERMINING CONCENTRATIONS OF METALS IN BAAP SOIL THAT ARE PROTECTIVE OF GROUNDWATER. FOR THIS EXAMPLE, LEAD (PB) IN SUBSURFACE SOIL AT THE 1949 PIT IS MODELLED. PER THE ATTACHED DESCRIPTION OF THE MODELING EFFORT, INITIAL SCREENING OF METALS WAS CONDUCTED USING THE LINEAR PARTITIONING MODEL. PRIOR TO CALCULATING THE SOIL TARGET CONCENTRATION USING THE LINEAR PARTITIONING MODEL, THE VALUE OF THE LEACHATE CONCENTRATION IN GROUNDWATER IS DETERMINED BY MULTIPLYING THE WPAL BY THE DILUTION ATTENUATION FACTOR (DAF). THE METHOD FOR CALCULATING THE DAF IS PROVIDED (AS CORRECTED) IN NR 720.

CALCULATIONS FOR DAF AT 1949 PIT:

$$DAF = 1 + \frac{KId}{RL}$$

$K = 41{,}386$ FT/YR
$I = 0.0014$ FT/FT
$d = 10$ FEET
$R = 10$ IN/YR

SEE PREVIOUS EXAMPLE

L = HORIZONTAL EXTENT OF CONTAMINATED SOIL PARALLEL TO THE HYDRAULIC GRADIENT
= 680 FEET (ESTIMATED LENGTH OF 1949 PIT)

$$\Rightarrow DAF = 1 + \frac{(41{,}386\ \text{FT/YR})(0.0014\ \text{FT/FT})(10\ \text{FT})}{(10/12\ \text{FT})(680\ \text{FT})}$$

$$DAF = 2.02$$

CALCULATION FOR LEACHATE CONCENTRATION IN GROUNDWATER:

$C_L = \text{WPAL} \times 2.02$

$C_L = 5\ \mu g/l \times 2.02$

$= \underline{10.1\ \mu g/l}$

PROJECT	COMP. BY	JOB NO.
EXAMPLE CALCULATIONS	JSM	6853-09
	CHK. BY N. S[illegible]	DATE 4/6/94

(6)

CALCULATE SOIL TARGET CONCENTRATION FOR PB USING THE LINEAR PARTITIONING MODEL:

$$C_l = C_s / K_d$$

C_l = CONCENTRATION OF LEACHATE
= 10.1 μg/l = 0.0101 mg/l

K_d = SOIL-WATER PARTITION COEFFICIENT
= 99 ml/g (MEDIAN VALUE FROM LITERATURE)

C_s = SOIL TARGET CONCENTRATION

REARRANGING THE EQUATION:

$$C_s = C_l \times K_d$$

$$= 0.0101 \times 99$$

$$C_s = 1.0 \text{ mg/kg}$$

BECAUSE SCREENING PB WITH THE LINEAR PARTITIONING MODEL INDICATES THAT THE SOIL TARGET CONCENTRATION (1.0 mg/kg) IS LESS THAN THE MAXIMUM PB CONCENTRATION (5,371 mg/kg) IN SOIL, ADDITIONAL MODELING WAS CONDUCTED TO ESTIMATE THE ATTENUATING EFFECTS OF PARTITIONING PER THE JURY MODEL. HOWEVER, THE INITIAL RUNS USING THE JURY MODEL FOR METALS SHOWED NO SIGNIFICANT DIFFERENCE IN THE RESULTS FOR TARGET SOIL CONCENTRATION THAN THOSE OBTAINED USING THE LINEAR PARTITIONING MODEL. CONSEQUENTLY, REMEDIATION GOALS FOR METALS WERE CALCULATED USING ONLY THE LINEAR PARTITIONING MODEL.

APPENDIX A.3

MODELING DESCRIPTION

MODELING DESCRIPTION
SOIL REMEDIATION GOALS
BADGER ARMY AMMUNITION PLANT

The WDNR has requested that modeling be conducted for contaminants of concern relative to their potential for leaching from soils and migrating to groundwater and resulting in concentrations in groundwater above the PALs. In response to this request, ABB-ES has performed the following analysis. First, a screening level using the organic leaching model (OLM) for organics, and a linear partitioning model for metals, was conducted for all compounds for which a PAL was available. This was coupled with estimates of mixing factors of leachate with groundwater based on the site size, recharge and groundwater flow beneath the site. For compounds which were still of concern, more detailed modeling with the Jury model (Jury, et al., 1990) was conducted to include effects of partitioning through the soil column, volatilization, and degradation of the organics; and partitioning of the metals. The models used and the input parameters are described in the following sections. No modeling was attempted for anionic contaminants of concern (sulfate, nitrate/nitrite, or chloride) because no models exist to predict concentrations during migration of these constituents.

Mixing Factors

Dilution mixing factors for leachate reaching the groundwater were estimated from the mass balance approach described in the WDNR regulations as corrected. The equation includes a mixing of the leachate generated over the area of contamination by net recharge of infiltrating rain or snowmelt with the estimate of groundwater flowing through a mixing zone beneath the source area. Site areas and groundwater flow velocities were estimated based on RI data, and the recharge and mixing zones were taken as the default values of 10 inches per year and 10 feet unless site-specific data were available to provide other values. At the Deterrent Burning Ground, although there is a perched aquifer, the impact of contaminants at the site was modelled relative to the regional aquifer. To be conservative, the effect of the silty layer was ignored (data indicate low lateral migration rates), and the source area was projected to the regional groundwater.

Screening Level Models

The OLM (USEPA, 1986) is an empirical expression relating estimated leachate concentration to the compound solubility in water and concentration in waste or soil. It was derived by USEPA for the RCRA program from a large database of leachate and soil concentration for a large number of sites. While the model is not site specific, it does represent a best-fit estimate for leaching concentrations under actual site conditions. The equation for the OLM is:

$$cl = 0.00221*(s^{0.373})*(cw^{0.678})$$

where cl is the leachate concentration (mg/L)
s is the compound solubility in water (mg/L), and
cw is the concentration in waste or soil (ppm).

The equation actually has the form of a typical adsorption isotherm as compound partitioning is inversely related to compound solubility.

The linear partitioning model (often called the Summers model when coupled with the mixing zone dilution factor) is based on a simple equilibrium of leachate and soil concentrations. The model is simply:

$$cl = cw/Kd$$

where cl is the leachate concentration (mg/L)
cw is the concentration in waste or soil(ppm), and
Kd is the soil-water partition coefficient (ml/g).

Kd is further approximated as the normalized organic carbon partition coefficient (Koc) times the fraction organic carbon (foc).
The model is generally very conservative as the partition coefficients are determined from well-mixed solid and liquid phases, and from sorption rather than desorption experiments. For low fraction organic carbon settings (e.g., sand and gravel horizons), the linear partitioning model is considered to be inaccurate and inappropriate (Dragun, 1988).

Neither of the screening models considers other factors which may significantly affect migration potential or concentrations as the contaminant migrates. Where significant soil column thickness exists between the contaminant and the groundwater table, the result of volatilization, partitioning and degradation processes can greatly lower contaminant concentrations along the pathway, and eventually decrease the leachate concentrations actually reaching the groundwater. Soil target levels are commensurately greater than would be predicted by a screening level model. Further, the linear partitioning model, OLM, and the Jury model, described next, are inadequate to describe the complex interactions that govern the migration processes for metals. Soil and leachate pH and Eh, and soil geochemistry, are all important factors that may immobilize a metal whereas the aforementioned models have no built-in components to include the effects of these conditions. Unfortunately, no adequate models exist to model the migration of metals (or of the anionic constituents), although some geochemical models will predict localized equilibria.

Jury Model

The Jury model is a one-dimensional transport model which includes

effects of linear partitioning, dispersion, volatilization, and degradation processes. It was developed in the early 1980s and further refined for the California Department of Health. The article presenting the Jury model is attached for reference. It is quite similar to the model, IMPACT, later developed for the State of New Jersey for setting draft soil target levels (Korfiatis, et al., 1994). The Jury model assumes a uniform distribution of contaminant within a zone of specified thickness and depth within the soil column. Soil properties are entered as are the chemical/physical properties of the contaminant. Migration of single constituents is considered by the model requiring multiple runs for a range of constituents and distributions.

Input Parameters

Mixing zone dilution factors were calculated from data from the RI and default values for recharge and zone thickness (except for one instance where the thickness of TRCLE is well-defined). The required data also include source area size and orientation to flow, aquifer hydraulic conductivity, and hydraulic gradient. In several instances, it was possible to determine a single mixing zone factor for a number of similar sites (e.g., the spoil piles or the settling ponds), using a minimum or representative value for the mixing factor for these locations.

The leaching portion of the Summers model requires a Kd value which has been taken as literature derived Koc values (USEPA, 1989, 1990) times an assumed fraction organic carbon (foc) of 0.1% or 0.001. This is conservatively low, but reasonable for sand and gravel soils. The value of foc used will be discussed further in the results section. The value of the leachate used to determine the soil target level is the PAL times the mixing dilution factor. Kds for the metals were taken as median values from the literature (Baes and Sharp, 1983) for most site areas, but limited site-specific data for lead and chromium was available from total and TCLP analyses for some areas. This data was used where appropriate to estimate an average partition coefficient. No data was available in the literature for barium or mercury (only one value was available from the TCLP analyses), and so these two metals were not modelled.

The OLM expression can be rearranged algebraically to solve for the soil target level. Again, the input leachate concentration would be the PAL times the mixing dilution factor. The OLM requires the water solubility of the compound as input rather than the Kd. Solubility values are available for all organic compounds of concern from the literature.

The Jury model requires a number of parameter values to describe the water-soil, and water-air partitioning equilibria, degradation rate constants, and migration rates. The degradation rates were taken from Howard (1991), and represent the upper end of the range given by Howard for degradation in soil. The rates then represent a conservative rate for degradation to occur within the soil

column. Comparing these rates to rates given in the Impact model article showed them to be identical implying that the state of New Jersey accepts these values for degradation.

Results of the Modeling

As expected, the OLM provided somewhat higher soil target levels than the linear partitioning model for most of the compounds. For many compounds, the projected soil target levels estimated by the more conservative Summers model were below detectable limits. Only in a couple of instances were compounds eliminated by the screening level analysis, and the next step in the modeling process (use of the Jury model) was undertaken.

The Jury model indicated that in most instances, the added attenuation provided by volatilization and mainly degradation was sufficient to protect groundwater to the low PAL criteria. BEHP, benzene, TRCLE, and for most areas, 26-DNT, gave soil targets above maximum detected values. For 24-DNT, there was still an indicated potential for impacting groundwater, although some areas were indicated as only a marginal potential. The reasons for this relative to the 26-DNT, which in most instances was not a problem, was the lower Koc for 24-DNT and its slightly longer estimated half-life.

The modeling for the metals at the screening level did not include any mechanisms that would attenuate migration other than by retarding migration rates. Hence the source area is modeled as having nearly a direct impact on groundwater , but with a delay in time. For most metals, migration travel times were between several hundred to several thousand years, indicating the relative immobility of the metals.

Uncertainty and Sensitivity

The analysis that has been performed is relatively conservative, primarily based on uncertainty in some of the input parameters, and the lack of adequate models or data to model migration of metals. The primary uncertainties regarding the actual risk presented by the 24-DNT (which remains as the principal organic constituent posing a potential threat to groundwater), are in the Koc value for that compound, the foc value used, and the conservative use of the high end of the range of half-lives given in Howard. The reported data for Koc for 24-DNT give two values, 240 and 45, the lower of the two being used in the analysis, but given the reported solubilities for both 26-DNT and 24-DNT (probably more accurately determined parameter values), the reported Kocs of 92 and 45 appear to be much too low. Either use of the greater Koc value or of a slightly higher value of foc would greatly alter the estimated 24-DNT target values. For example, rerunning the Jury model for the Deterrent Burning Ground with an foc of 0.002 instead of 0.001, raised the target level for 24-DNT from 84 to 26,460 ppb, a factor of over 300, and 24-DNT would cease to be a concern to groundwater

at most locations.

Results at the Deterrent Burning Ground were obtained without inclusion of potential effects of the low-permeable zone that supports the perched system there. Due to the fine-grained materials, recharge rates and area of impact on the regional aquifer underestimated. These are not quantifiable with the available data, but would substantially decrease estimated effects of leachate on the regional system.

Conclusions

While the modeling has demonstrated a probable lack of impact of most organics at the various sites on groundwater (relative to the PALs), the limitations of the modeling, the necessary selection of conservative values for several parameters, still indicate a potential for impact on groundwater at some areas for 24-DNT and for the metals (some at very low concentrations). In order to pursue this question of potential impact further, it would probably be necessary to perform some leaching tests and more precisely determine a probable range for foc at the site.

References

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PROJECT	COMP. BY	JOB NO.
Badger	RAL	
	CHK. BY	DATE 3/22/94

Metals w/PALs

		Lit.(*)	RPA	PBG/SUB	PBG/SS	
Arsenic	5 µg/l	2/6.7/18	–	–	–	(As(V))
Barium	200	–	–	–	–	
Cadmium	1	1.3/6.7/27	–	–	–	
Chromium	5	1.2/37/1800	416/1	165/2	2635/1	
Iron	150	1.4/55/1000	–	–	–	
Mercury	0.2	–	3580/1	–	–	
Manganese	25	0.2/150/10000	–	–	–	
Lead	5	4.5/99/7640	637	49.3	531	
Selenium	1	1.2/2.7/8.6	–	–	–	(Se(IV))
Zinc	2500	0.1/16/8000	–	–	–	

(*) Baes and Sharp.

Other Inorganics

Chloride	125,000	Cannot model leaching of these constituents.
Nitrate/Nitrite	2,000	
Sulfate	125,000	

Organics	H(dim)	PAL µg/L	Sol. (mg/l)	VP (mm Hg)	H atm-m³/mole	Koc ml/g	MW	$t_{1/2}$ (d)
BEHP	1.55E-5	0.3	0.285	2E-7	0.000000361	5900	391	395
VC	3.53	0.0015	2670	2660	0.0819	57.	63	182
Benzene	0.24	0.067	1750	95.2	0.00558	83	78	16
Carbon Tet	1.04	0.5	757	90	0.0241	110	154	365
Chloroform	0.124	0.6	820	150.2	0.00288	44	119	182
1,2-DCA	0.0421	0.05	8520	64.0	0.000978	14	99	182
2,4-DNT	2.2E-4	0.005	240	0.0053	0.0000051	45/250	182	267
2,6-DNT	1.41E-4	0.005	180	0.018	0.00000327	92	182	182
Toluene	0.274	68.6	535	28.1	0.00637	300	92	22
2-butanone	1.18E-3	90	268,000	77.5	0.0000274	4.5	72	7
naphthalene	0.0495	8	31.7	0.23	0.00115	1300	128	48
1,1,1-TCA	0.620	40	1500	123	0.0144	152	133	274
1,1,2-TCA	0.050	0.06	4500	30.0	0.00117	56	133	365
TCE	0.392	0.18	1100	57.9	0.0091	126	132	365

Chemical/physical properties from tables in RI and supplemented by EPA sources. Half-lives are for high end range (lowest degradation rates) as given in Howard.

WATER RESOURCES RESEARCH, VOL. 26, NO. 1, PAGES 13–20, JANUARY 1990

Evaluation of Volatilization by Organic Chemicals Residing Below the Soil Surface

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Although volatile organic compounds located in buried waste repositories or distributed through the unsaturated soil zone have the potential to migrate to the atmosphere by vapor diffusion, little attention has been paid in the past to estimating the importance of volatilization losses. In this paper a screening model is introduced which evaluates the relative volatilization losses of a number of organic compounds under standard soil conditions. The model is an analytic solution to the problem wherein the organic chemical is located at time zero at uniform concentration in a finite layer of soil covered by a layer of soil devoid of chemical. The compound is assumed to move by vapor or liquid diffusion and by mass flow under the influence of steady upward or zero water flow while undergoing first-order degradation and linear equilibrium adsorption. Loss to the atmosphere is governed by vapor diffusion through a stagnant air boundary layer. Calculations are performed on 35 organic compounds in two model soils with properties characteristic of sandy and clayey soil. The model identifies those compounds with high potential for loss during 1 year after incorporation under 100 cm of soil cover and also is used to calculate the minimum soil cover thickness required to reduce volatilization losses to insignificant levels during the lifetime of the compound in the soil. From the latter calculation it was determined that certain compounds may volatilize from deep subsurface locations or even groundwater unless the soil surface is sealed to prevent gas migration.

INTRODUCTION

Volatile organic chemicals may enter the soil from a variety of sources. They may be deliberately confined in waste repositories or landfills that are covered with a layer of soil. They may inadvertently enter the vadose zone from a surface spill or a leaking storage tank, which places at least part of the chemical spill below the ground. Once these chemicals are introduced into the vadose zone, they may ultimately migrate to the groundwater and may be present either as a dissolved constituent or as part of an immiscible fluid such as gasoline which floats on top of the groundwater table. Some of these contaminated locations may contain considerable chemical mass, which can potentially volatilize for years.

Although at one time little concern was raised over volatile emissions of potentially hazardous organic chemicals from soil, this is no longer the case. Abandoned waste repositories such as the Stringfellow Acid Pits in California have been covered with clay caps to prevent escape of volatile compounds to the atmosphere [*Ember*, 1985]. Concentrated pesticide residues have been detected in atmospheric aerosols above farmland in California and in Maryland [*Glotfelty et al.*, 1987].

Many of the volatile organic chemicals found in groundwater and in landfills have been found to have adverse health effects in toxicology studies. For example, benzene, a common constituent of U.S. groundwaters, has been identified as a human carcinogen by the National Institute for Occupational Safety and Health [*Office of Technology Assessment*, 1987]. Much attention has been focused on the potential exposure of humans via drinking water to trichloroethylene (TCE) a common industrial solvent widely found in groundwater, and this attention has led to substantial numbers of wells being closed down when high TCE levels are observed. However, the extent of and health implications of long-term exposure from volatile emissions of organic chemicals in groundwater or buried soil repositories are poorly understood at present [*Andelman and Underhill*, 1987].

The purpose of this paper is to describe a chemical transport and reaction model that may be used to evaluate the extent of volatilization to the atmosphere from organic compounds that are located below the soil surface. Because the model is based on a number of simplifying assumptions, it is not intended to be used to simulate volatilization at a specific site. Rather, it has been designed as a screening model to assess the volatilization potential of a large number of compounds under standard soil and environmental conditions. By comparing the behavior of different compounds in identical settings, chemicals with significant potential for volatilization may be identified. Moreover, compounds may be grouped into similar behavior classes so that chemicals for which there is no experimental information may be linked to compounds which have been monitored under natural conditions.

THEORY

The mathematical model used to make the calculations presented in this paper is derived by a transformation of the behavior assessment screening model published by *Jury et al.* [1983], which is based on the following assumptions:

1. Chemicals may reside in three phases in the soil: an adsorbed phase, whose concentration C_s is expressed in micrograms per gram of soil; a dissolved phase, whose concentration C_l is expressed in micrograms per cubic centimeter of soil solution; and a gaseous phase, whose concentration C_g is expressed in micrograms per cubic centimeter of soil air. The total concentration C_T in micrograms per cubic centimeter of soil is thus

$$C_T = \rho_b C_s + \Theta C_l + aC_g \qquad (1)$$

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Paper number 89WR01546.
0043-1397/90/89WR-01546$05.00

where ρ_b (g cm^{-3}) is soil bulk density, θ is volumetric water content, and a is volumetric air content.

2. The chemical flux J_s (μg cm^{-2} d^{-1}) is the sum of the vapor flux J_g and the flux of dissolved solute J_l. The vapor flux J_g is given by the modified form of Fick's law of diffusion:

$$J_g = -D_g\, \partial C_g/\partial z = -\xi_g D_g^a\, \partial C_g/\partial z \tag{2}$$

where D_g and D_g^a (cm^2 d^{-1}) are the gaseous diffusion coefficients in soil and air, respectively, and ξ_g is a factor accounting for vapor diffusion porosity and tortuosity effects. The flux of dissolved solute J_l is expressed as the sum of the liquid diffusion flux and the convective flux:

$$J_l = -D_l\, \partial C_l/\partial z + J_w C_l = -\xi_l D_l^w \partial C_l/\partial z + J_w C_l \tag{3}$$

where J_w (cm d^{-1}) is the volumetric soil water flux, D_l and D_l^w (cm^2 d^{-1}) are the liquid diffusion coefficients in soil and pure water, respectively, and ξ_l is a factor accounting for liquid diffusion porosity and tortuosity effects.

3. The vapor phase and liquid phase porosity and tortuosity factors are assumed to obey the model of *Millington and Quirk* [1961]

$$\xi_g = a^{10/3}/\phi^2 \tag{4a}$$

$$\xi_l = \Theta^{10/3}/\phi^2 \tag{4b}$$

where $\phi = \Theta a + \Theta$ is total soil porosity.

4. The chemical is assumed to undergo first-order biological/chemical degradation in the soil with a rate constant μ (d^{-1}) that is related to the effective half-life τ (days) by

$$\mu = \ln(2)/\tau \tag{5}$$

5. The chemical moves in one dimension through the soil in accordance with the principle of mass balance:

$$\partial C_T/\partial t + \partial J_s/\partial z + \mu C_T = 0 \tag{6}$$

6. The adsorbed and dissolved phases are assumed to undergo reversible, linear equilibrium adsorption, as expressed by

$$C_s = K_d C_l = f_{oc} K_{oc} C_l \tag{7}$$

where K_d (cm^3 g^{-1}) is the distribution coefficient, f_{oc} is the soil organic carbon fraction, and K_{oc} (cm^3 g^{-1}) is the organic carbon partition coefficient.

7. The dissolved and gaseous phases are assumed to be in equilibrium in accordance with a modified Henry's law:

$$C_g = K_H C_l \tag{8}$$

where K_H is the dimensionless form of Henry's constant.

8. The soil properties, a, Θ, ϕ, ρ, and f_{oc} are assumed to be constant in space and time, as is the temperature.

9. Water flux J_w is constant in space and time (upward, downward, or zero).

10. Volatilization of chemical vapor to the atmosphere is assumed to occur by vapor diffusion through a stagnant air boundary layer of thickness d (cm), above which the chemical concentration is zero. Thus the upper boundary condition at the soil surface ($z = 0$) is

$$J_s(o, t) = -D_g^a C_g(o, t)/d = -hC_g(o, t) \tag{9}$$

where $h = D_g^a/d$ (cm d^{-1}) is the boundary layer transfer coefficient. *Jury et al.* [1983] discuss ways of estimating values of d. The minus sign is required in (9) because the z direction is positive downward.

Under these assumptions the transport equation derived from the flux equations (2)–(3) and the mass balance equation (6) may be simplified to [*Jury et al.*, 1983]

$$\frac{\partial C_T}{\partial t} + \mu C_T = D_E \frac{\partial^2 C_T}{\partial z^2} - V_E \frac{\partial C_T}{\partial z} \tag{10}$$

where

$$V_E = J_w/(\rho_b f_{oc} K_{oc} + \Theta + aK_H) \tag{11}$$

is the effective solute velocity, and

$$D_E = [(a^{10/3} D_g^a K_H + \Theta^{10/3} D_l^w)/\phi^2]/(\rho_b f_{oc} K_{oc} + \theta + aK_H) \tag{12}$$

is the effective diffusion coefficient.

In this notation the upper boundary condition may be rewritten in terms of total concentration as

$$-D_E \partial C_T/\partial z + V_E C_T = -H_E C_T \qquad \text{at } z = 0 \tag{13}$$

where

$$H_E = hK_H/(\rho_b f_{oc} K_{oc} + \Theta + aK_H) \tag{14}$$

Jury et al. [1983] solved (10) with the upper boundary condition (13) for the case of a chemical initially incorporated to depth L at a uniform concentration C_o

$$\begin{aligned} C_T(z, 0) &= C_o \qquad 0 < z < L \\ C_T(z, 0) &= 0 \qquad z > L \end{aligned} \tag{15}$$

and the lower boundary condition

$$C_T(\infty, t) = 0 \tag{16}$$

The solutions for the concentration and the flux at the soil surface [*Jury et al.*, 1983, equations 24 and 25] are

$$\begin{aligned} C_T(z, t; L) = \tfrac{1}{2} C_o \exp(-\mu t) \Bigg\{ &\operatorname{erfc}\left[\frac{(z - L - V_E t)}{(4D_E t)^{1/2}}\right] \\ &- \operatorname{erfc}\left[\frac{(z - V_E t)}{(4D_E t)^{1/2}}\right] + (1 + V_E/H_E) \\ &\cdot \exp(V_E z/D_E)\left[\operatorname{erfc}\left(\frac{(z + L + V_E t)}{(4D_E t)^{1/2}}\right)\right. \\ &\left. - \operatorname{erfc}\left(\frac{(z + V_E t)}{(4D_E t)^{1/2}}\right)\right] + (2 + V_E/H_E) \\ &\cdot \exp\{[H_E(H_E + V_E)t + (H_E + V_E)z]/D_E\} \\ &\left[\operatorname{erfc}\left(\frac{[z + (2H_E + V_E)t]}{(4D_{Et})^{1/2}}\right)\right. \\ &\left.\left. - \exp(H_E L/D_E) \operatorname{erfc}\left(\frac{[z + L + (2H_E + V_E)t]}{(4D_E t)^{1/2}}\right)\right]\right\} \end{aligned} \tag{17}$$

TABLE 1. Chemodynamic Fate Properties of Volatile Organic Compounds Used in the Simulations

Compound	K_H	K_{oc}, $cm^3 g^{-1}$	$t_{1/2}$, days
Acrolein	.0028 ~~0.337E+01~~	24 ~~0.100E+01~~	7-30 ~~0.300E+03~~
Benzene	0.220E+00	0.800E+02	5-16 ~~0.365E+03~~
Benzo B Fluoranthene	0.690E−02	0.480E+07	0.100E+03
Bromoethane	0.820E+01	0.900E+01	0.300E+02
Chlordane	0.100E−03	0.480E+03	0.100E+03
Chloroethane	0.615E+00	0.250E+02	0.300E+02
Chloroethene	0.44 ~~0.152E+01~~	56 ~~0.200E+01~~	30-180 ~~0.300E+02~~
Chloroform	0.120E+00	0.290E+02	0.100E+03
Chloromethane	0.162E+01	0.600E+01	0.120E+03
2-Chloronapthalene	0.220E−01	0.115E+04	0.144E+04
1,2-dibromo-3-chloropropane (DBCP)	0.400E−03	0.129E+03	0.100E+04
Dichlorodifluoromethane	0.109E+03	0.111E+03	0.100E+05
1,1-Dichloroethane	0.177E+00	0.460E+02	0.450E+02
1,2-Dichloroethane	0.380E−01	0.220E+02	0.900E+02
Dichloromethane	0.128E+00	0.130E+02	0.100E+03
2,4-Dichlorophenol	0.200E−03	0.447E+03	0.160E+03
s-ethyl dipropylthiocarbanate (EPTC)	0.590E−03	0.280E+03	0.300E+02
Ethylene dibromide	0.350E−01	0.440E+02	0.365E+04
Heptachlor	0.341E+00	0.681E+04	0.220E+04
Hexachlorocyclohexane	0.300E−03	0.234E+04	0.725E+03
Methyl ethyl ketone	0.102E−02	0.100E+02	0.100E+03
Methyl isobutyl ketone	0.210E−02	0.220E+02	0.100E+03
Pentachlorophenol	0.100E−03	0.940E+05	0.100E+02
Phorate	0.310E−03	0.660E+03	0.820E+02
Pyrene	0.500E−03	0.197E+06	0.500E+03
Tetrachloro dibenzo-p-dioxin (TCDD)	0.320E−02	0.138E+07	0.365E+03
Toluene	0.280E+00	0.980E+02	4-22 ~~0.500E+01~~
Toxaphene	0.125E+01	0.632E+03	0.365E+04
Triallate	0.790E−03	0.360E+04	0.100E+03
1,1,1-Trichloroethane	0.146E+01	0.113E+03	0.365E+03
Trichloroethylene	0.380E+00	0.138E+03	0.730E+03
Trichloromethane	0.120E+00	0.600E+02	0.500E+02
Xylene	7.28 ~~0.940E+04~~	50 ~~0.295E+03~~	7-30 ~~0.110E+03~~

Read 0.337E+01 as 0.337×10^1.

Use SPHEM Data when available for K_H, K_{oc}

's correction in WRR Vol 28, No. 2 pp 607, 608

$$J_s(0, t; L) = \tfrac{1}{2} C_o \exp(-\mu t) \left\{ V_E \left[\operatorname{erfc}\left(\frac{V_E t}{(4D_E t)^{1/2}} \right) - \operatorname{erfc}\left(\frac{(L + V_E t)}{(4D_E t)^{1/2}} \right) \right] + (2H_E + V_E) \cdot \exp[H_E(H_E + V_E)t/D_E] \left[\exp(H_E L/D_E) \cdot \operatorname{erfc}\left(\frac{[L + (2H_E + V_E)t]}{(4D_E t)^{1/2}} \right) - \operatorname{erfc}\left(\frac{[(2H_E + V_E)t]}{(4D_E t)^{1/2}} \right) \right] \right\} \tag{18}$$

The application of this behavior assessment model to assessing the volatility, persistence, and leaching of deposits of chemicals is illustrated by *Jury et al.* [1984*a*, *b*, *c*].

Because (10) and (13)–(15) are linear equations, the principle of superposition may be used to derive the solution to (10), (13), and (16) for the case of a chemical incorporated at uniform concentration in a finite buried layer of soil as represented by the initial condition

$$\begin{aligned} C_T(z, 0) &= 0 \qquad && 0 < z < L \\ C_T(z, 0) &= C_o \qquad && L < z < L + W \\ C_T(z, 0) &= 0 \qquad && z > L + W \end{aligned} \tag{19}$$

where W is the thickness of the layer of incorporation of the chemical.

This solution is given by

$$C_T^b(z, t) = C_T(z, t; L + W) - C_T(z, t; L) \tag{20}$$

$$J_s^b(o, t) = J_s(o, t; L + W) - J_s(o, t; L) \tag{21}$$

where the superscript b denotes a solution to the buried chemical initial condition and $C_T(z, t; L+W)$ and $J_s(o, t; L+W)$ are the solutions (17) and (18), respectively, with $L \rightarrow L+W$. Equations (20) and (21) are used in all the calculations to follow. In addition, the cumulative mass volatilized from the soil during a specified time period is calculated with the equation given in Appendix A.

RESULTS

Table 1 summarizes the environmental fate or "chemodynamic" properties of 35 volatile organic compounds. The list in Table 2 was compiled from measured or estimated values given by *Jury et al.* [1984*b*], *Rao et al.* [1985], *Wilkerson et al.* [1984], and *Ryan et al.* [1988]. In cases where the values have been estimated crudely, such as for the 10-year half-life of ethylene dibromide [*Rao et al.*, 1985], the environmental fate properties may be significantly in error. Nonetheless, the half-life values, which are the most difficult to estimate, are probably accurate enough to provide a reasonable as-

TABLE 2. Standard Values of Soil and Chemical Properties Used in the Simulations

Property	Symbol	Sandy Soil	Clayey Soil	Units
Porosity	ϕ	0.4	0.5	···
Bulk density	ρ_b	1.59	1.32	g cm^{-3}
Water content	Θ	0.18	0.375	···
Air content	a	0.22	0.125	···
Organic C fraction	f_{oc}	0.0075	0.025	···
Gaseous diffusion coefficient	D_v^a	4320	4320	cm^2 d^{-1}
Liquid diffusion coefficient	D_l^w	0.432	0.432	cm^2 d^{-1}
Boundary layer thickness	d	0.5	0.5	cm
Incorporated layer thickness	W	30	30	cm
Depth to incorporated layer	L	100	100	cm

TABLE 3. Cumulative Volatilization Losses of Chemicals During the First Year After Placement Below 1 m Expressed as a Percent of the Mass Initially Present Between 1.0 and 1.3 m

Compound	Sandy Soil	Clay Soil
Dichlorodifluoromethane	87.5	67.3
Acrolein	79.0	47.2
Xylene	72.5	45.2
Chloromethane	66.9	22.3
1,1,1-Trichloroethane	61.8	4.9
Chloroethene	54.2	22.1
Bromomethane	51.8	14.7
Toxaphene	41.5	···
Trichloroethylene	41.2	0.1
Benzene	34.3	0.01
Dichloromethane	29.7	0.2
Chloroethane	27.5	0.2
Chloroform	21.2	0.01
Ethylene dibromide	14.4	···
1,1-Dichloroethane	11.1	···
1,2-Dichloroethane	7.1	···
Trichloromethane	6.2	···
Toluene	0.1	···

No water evaporation.

sessment of the relative persistence of the compound in a biologically active surface zone of soil.

The screening model assessments of volatility from buried soil are run under ideal scenarios representing a soil with uniform porosity, bulk density, water content, and organic carbon fraction. In this study, two contrasting soil types will be used in the simulations, chosen to have properties characteristic of a relatively coarse-textured sandy soil and a finer-textured clayey soil. The standard values for the properties of these two soils are given in Table 2.

As an example of the effect of soil type on results of the screening simulations, Figure 1 shows a plot of the volatilization flux as a function of time (using (21)) and the final soil concentration as a function of depth (using (20)) for benzene during the first year after placement in a 30-cm-thick layer located 100 cm below the surface of a sandy and a clayey soil when water evaporation is negligible. In the sandy soil the benzene volatilization flux quickly rises to a maximum at about 30 days and remains high thereafter. In contrast, the flux from the clayey soil does not reach a maximum during

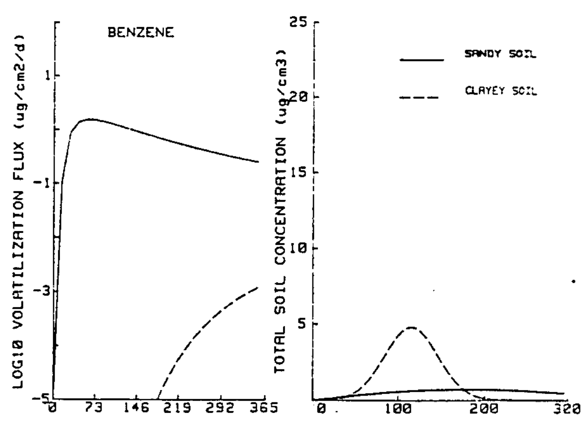

Fig. 1. Calculated volatilization flux and final soil concentration of benzene during 1 year after incorporation between 100 and 130 cm at a concentration of 25 μg cm^{-3}.

the first year and is more than 2 orders of magnitude less than the flux from the sandy soil after 1 year. The final soil concentration of benzene is very diffuse after 1 year in the sandy soil but fairly narrow in the clayey soil. The calculated mass balances for the two cases after one year are 34.3% volatilized, 38.6% degraded, and 27.1% remaining in the sandy soil and 0.01% volatilized, 50% degraded, and 49.99% remaining in the clayey soil. Thus the sandy soil cover clearly provided inadequate resistance to volatilization into the atmosphere for this compound.

Screening for Relative Volatility (in the Absence of Water Evaporation)

The 35 compounds given in Table 1 have a wide range of chemodynamic properties. By running identical buried chemical screening tests on each compound, one is able to identify the relative order of volatility for the group of chemicals under the two contrasting soil regimes.

Table 3 summarizes the percent of the initial mass which has volatilized for each chemical during 1 year after incorporation between 100 and 130 cm, arranged from high to low volatility. Those compounds in Table 1 not listed in Table 3 had insignificant volatilization loss. The first seven compounds in Table 3 show significant losses in both the sandy soil and the clay soil, ranging from a high of nearly 90% for dichlorodifluoromethane in the sandy soil to a low of 4.9% for 1,1,1-trichloroethane in the clay soil. Except for these seven chemicals, all other compounds had insignificant volatilization during the first year in the clay soil. In contrast, 11 additional compounds manifested significant volatilization losses in the sandy soil during the first year of volatilization after placement. This strong dependence on soil conditions indicates how important the soil cover type is in regulating volatile losses to the atmosphere.

Effect of Soil Cover Thickness

Figures 2 and 3 show the percent of initial benzene mass incorporated in a 30-cm layer that has volatilized to the

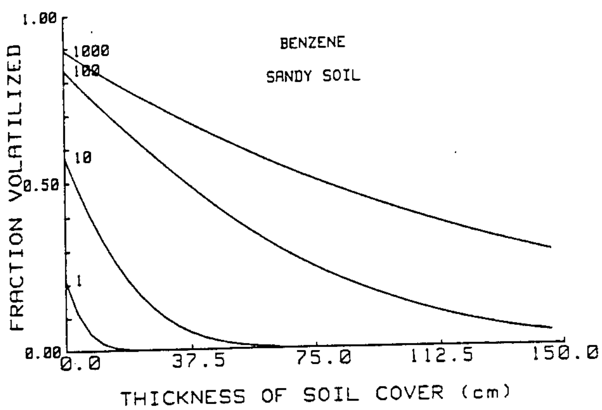

Fig. 2. Cumulative volatilization losses of benzene from sandy soil as a function of soil cover thickness and time (labeled in days), expressed as a fraction of the mass initially present in a 30-cm-thick layer (no water evaporation).

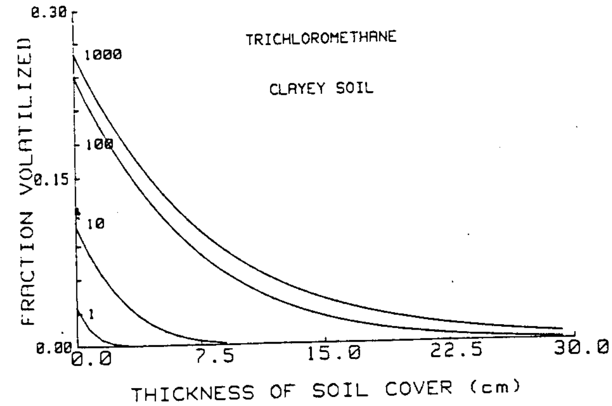

Fig. 4. Cumulative volatilization losses of trichloromethane from clayey soil as a function of soil cover thickness and time (labeled in days), expressed as a fraction of the mass initially present in a 30-cm-thick layer (no water evaporation).

atmosphere after varying time periods between 1 and 1000 days as a function of the thickness of the overlying soil cover in sandy and clayey soil, respectively. These two figures also illustrate both the differences between the extent of benzene loss by volatilization in the sandy and clayey soils in a given time period and the effect of increasing time on the cumulative loss of benzene vapor to the atmosphere. For example, after 100 days, very little benzene has escaped to the atmosphere of the sandy soil when buried below 150 cm. However, a 150-cm soil cover thickness does not restrict volatilization over 1000 days, and approximately 30% of the benzene initially present will escape to the atmosphere during this time period. In contrast, a compound like trichloromethane, which has a much shorter half-life than benzene, shows little difference in volatilization loss to the atmosphere after 100 and 1000 days (Figure 4), because it has degraded to a low concentration by 100 days. Thus for clayey soil cover thicknesses of greater than 30 cm, volatilization losses can essentially be eliminated for this chemical. This graph suggests that optimum soil covers may be designed for any volatile compound that degrades in soil by selecting layer thicknesses that create diffusive travel times to the surface which are significantly in excess of the biological half-life of the compound in the soil.

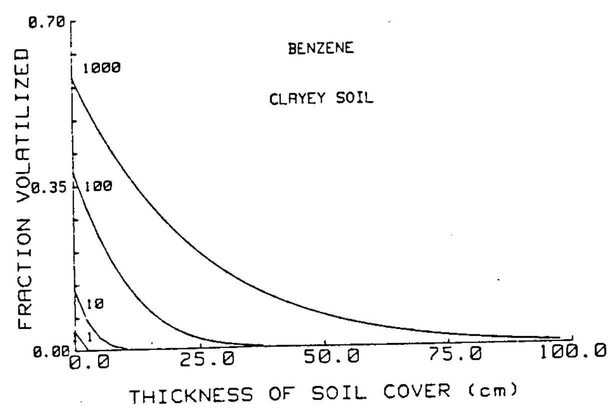

Fig. 3. Cumulative volatilization losses of benzene from clayey soil as a function of soil cover thickness and time (labeled in days), expressed as a fraction of the mass initially present in a 30-cm-thick layer (no water evaporation).

Calculation of Limiting Cover Thickness

As shown in Appendix B, the fractional cumulative volatilization loss, by diffusion alone, of a compound covered by a thickness L of soil with uniform properties after an infinite time is given approximately by

$$V_c^b(\infty)/M_o = \exp\left[-L(\mu/D_E)^{1/2}\right] \tag{22}$$

Thus for $L \gg (D_E/\mu)^{1/2}$, chemical volatilization losses to the atmosphere will be insignificant when water evaporation is not present. Table 4 summarizes values of cover thickness L calculated with (22) for the sandy and clayey soils under the restriction that mass losses by volatilization be held to less than 0.7% (exp (-5)) during the lifetime of the chemical in the ground. Notable in this table are the enormous differences in cover thickness under the two conditions, ranging for a sandy soil from a low of 1 mm for pentachlorophenol and chrysene to a high of 166 m for dichlorodifluoromethane. Clearly, the latter compound cannot be restricted from volatilization losses to the atmosphere even when present in groundwater which resides a significant distance below the soil surface. In contrast, many of the reasonably volatile compounds such as benzene, bromomethane, etc., will volatilize significantly when covered by thin layers of soil but will probably not reach the atmosphere to any great extent when moving upward from deep groundwater tables, providing that biological degradation is not confined to shallow surface layers.

Effect of Water Evaporation

The previous scenarios have all assumed that the water phase is stagnant during the chemical vapor diffusion process. However, under certain conditions, such as when shallow water tables are present below soil surfaces that do not receive frequent water inputs, prolonged upward flow of water may occur. In such cases, compounds that are not significantly adsorbed and that have reasonable concentrations in the dissolved phase may have their volatilization losses enhanced when water flow is upward. Table 5 summarizes the percent volatilization losses during the first year

TABLE 4. Soil Cover Thickness (cm) Required to Restrict Volatilization to Less Than 0.7% of Mass Incorporated in Soil

Compound	Sandy Soil	Clayey Soil
Acrolein	2,555.0	864.9
Benzene	657.8	126.3
Benzo B Fluoranthene	0.3	0.1
Bromoethane	873.9	298.1
Chlordane	4.0	3.9
Chloroethane	444.3	94.4
Chloroethene	936.6	378.8
Chloroform	378.2	75.1
Chloromethane	1,445.5	392.4
Chrysene	0.1	0.0
1,2-dibromo-3-chloropropane (DBCP)	41.3	23.8
Dichlorodifluoromethane	16,645.8	6,150.0
1,1-Dichloroethane	261.2	51.0
1,2-Dichloroethane	223.8	45.7
Dichloromethane	482.2	99.3
2,4-Dichlorophenol	6.8	5.1
s-ethyl dipropylthiocarbamate (EPTC)	6.0	2.9
Ethylene dibromide	1,086.7	217.9
Heptachlor	245.7	45.4
Hexachlorocyclohexane	7.7	4.9
Methyl ethyl ketone	48.5	20.6
Methyl isobutyl ketone	56.5	18.2
Pentachlorophenol	0.1	0.1
Phorate	4.9	3.1
Pyrene	0.9	0.5
Tetrachlorodibenzo-p-dioxin	0.7	0.2
Toluene	80.7	15.4
Toxaphene	1,934.1	362.1
Triallate	3.6	1.5
1,1,1-Trichloroethane	1,373.9	276.4
Trichloroethylene	976.2	185.8
Trichloromethane	205.8	40.0
Xylene	1,797.4	731.2

after incorporation for chemicals that are placed 100 cm below the surface and are subjected to 0.1 cm d^{-1} of steady upward water flow. Comparison of Table 5 with Table 3 shows that certain compounds such as ethylene dibromide and 1,2-dichloroethane can increase their volatilization fluxes significantly under this condition. Similarly, other compounds, such as methyl ethyl ketone, that do not volatilize at all under stagnant water conditions may actually have some potential for migrating more rapidly to the surface when steady water flow is occurring, even at the relatively low rates of 1 mm d^{-1}. The net result of the water flow process is to reduce the thickness of the covering soil layer by transporting the compound upward by mass flow.

Effect of Water Content

The chemical property that is principally responsible for volatilization of an organic chemical from a buried soil layer is the effective diffusion coefficient D_E (equation (12)). For the volatile compounds that reside principally in the vapor phase this coefficient is essentially proportional to the 10/3 power of the volumetric air content if one uses the tortuosity model (4) of *Millington and Quirk* [1961]. For this reason, increasing the water content of the confining layer significantly decreases volatilization flux over any time period. However, it may be difficult to maintain the water content of a landfill or waste repository at a high level, because this requires substantial inputs of water to the site. Because many of the volatile compounds in Table 1 also represent a potential groundwater threat, application of significant quantities of water may enhance the potential for downward leaching, especially if the repository is not lined effectively at its lower boundary. Thus, in a sense, management for groundwater protection by minimizing water input to the site will tend to maximize volatilization losses by allowing the confining soil layer to dry. This may be particularly harmful to clay liners, which may crack and greatly increase the upward diffusion coefficient in the interlayer between portions of the soil matrtix. Thus the optimal management practice for simultaneous groundwater and atmospheric protection may be to apply sufficient water to maintain a high level of water retention without allowing substantial quantities of water in excess of evaporative demand to occur.

CONCLUDING REMARKS

The screening model calculations presented in this paper are intended to evaluate the relative volatility of a large number of compounds, rather than the absolute volatility of a specific compound at a particular site. The 35 compounds evaluated here show a wide range of responses to soil covers of various types and thicknesses, and those compounds that show significant losses from the clayey soil cover of 100 cm are ones for which volatilization should be a cause of concern under general conditions.

The limiting soil cover thicknesses have been calculated under the assumption that the soil layer above the compound induces degradation at the rate characterized by the representative half-life of the compound. However, for those chemicals that require substantial cover thicknesses (e.g., 18 m of sandy soil for Xylene), the assumption of uniform degradation will not be appropriate in soils with shallow microbial activity. What this calculation implies for such compounds, then, is that volatilization is likely whenever the chemical is in the soil, unless the surface is completely sealed.

TABLE 5. Cumulative Volatilization Losses of Chemicals During the First Year After Placement Below 1 m Expressed as a Percent of the Mass Initially Present Between 1.0 and 1.3 m

Compound	Sandy Soil	Clay Soil
Dichlorodifluoromethane	91.3	77.1
Acrolein	85.6	84.7
Xylene	80.2	54.7
Chloromethane	77.0	42.7
1,1,1-Trichloroethane	73.4	21.4
Chloroethene	66.0	37.4
Bromomethane	64.3	30.0
Trichloroethylene	60.0	6.1
Toxaphene	58.3	3.8
Benzene	54.9	6.4
Ethylene dibromide	53.3	3.6
Dichloromethane	52.1	9.9
Chloroethane	44.2	4.8
Chloroform	42.8	4.4
1,2-Dichloroethane	29.9	2.2
1,1-Dichloroethane	27.6	1.0
Methyl ethyl ketone	23.3	3.8
Trichloromethane	20.9	0.4
Methyl isobutyl ketone	13.2	0.7
Toluene	2.6	...
Heptachlor	2.2	...
1,2-dibromo-3-chloropropane	0.2	...

Water Evaporation Rate is 0.1 cm d^{-1}

The assumption of uniform water content, which certainly is greatly in error when the compound must move upward from groundwater, will seriously underestimate the diffusive travel time from a source which must diffuse through a very wet region. However, if this wet region is far below the soil surface, degradation will also be reduced and the compound will survive its passage through the zone and be free to move through the drier soil above.

The model does not include a nonaqueous phase liquid (NAPL) concentration, although many compounds spilled onto soil or present in landfills may be partly found in this form. If the nonaqueous phase can be represented by a simple partition relation similar to that used for the other phases and if transport of the nonaqueous phase is negligible after deposition, then the model may be easily modified to incorporate a NAPL component, with its partition coefficient appearing as an additional chemodynamic property.

Finally, the screening model discussed above may be useful in producing an exposure assessment for individuals living in the vicinity of waste repositories or landfills. Current risk assessments of such locations are conducted with relatively crude models of atmospheric contamination. The flux estimates from this screening model could easily be coupled to a near-atmosphere mixing cell or dispersion model to predict long-term ambient concentrations of volatile pollutants.

Appendix A

The cumulative volatilization loss $V_c(t)$ from the soil surface between times o and t for a chemical initially deposited between depths o and L at concentration C_o is given by

$$V_c(t) = \int_o^t -J_s(o, t'; L)\, dt' \qquad \text{(A1)}$$

where $J_s(o, t; L)$ is given by (18). Note that the minus sign is used because the volatilization flux at the surface, J_s, is negative (opposite in direction to a positive downward z), while the cumulative loss is considered positive. Although this integral may be evaluated numerically, errors may result for volatilization fluxes from chemicals with large K_H unless extremely small intervals of time are used in the numerical integration.

Equation (A1) may be evaluated analytically by a straightforward, albeit tedious, application of the Laplace transform method, with the result

$$V_c(t) = -\frac{C_o}{2}\left\{\frac{V_E}{\mu}[1 - \exp(-\mu t)[S_1 - S_2]] - \frac{(V_E + 2H_E)}{(\mu - \xi)}\right.$$
$$\cdot [1 - \exp(-\mu t)[S_3 - S_4]] + \exp[-P/2 - \beta(L(D_E)^{1/2})]$$
$$\cdot\left[\frac{(V_E + 2H_E)}{2(\mu - \xi)} - \frac{V_E}{2\mu} - \frac{(V_E + 2H_E)^2}{4(\mu - \xi)\beta(D_E)^{1/2}} + \frac{V_E^2}{4\mu\beta(D_E)^{1/2}}\right]S_5$$
$$+ \exp[-P/2 + \beta(L(D_E)^{1/2})]$$
$$\cdot\left[\frac{(V_E + 2H_E)}{2(\mu - \xi)} - \frac{V_E}{2\mu} + \frac{(V_E + 2H_E)^2}{4(\mu - \xi)\beta(D_E)^{1/2}} - \frac{V_E^2}{4\mu\beta(D_E)^{1/2}}\right]S_6$$
$$\left. + \frac{1}{2\beta}\left[\frac{(V_E + 2H_E)^2}{(\mu - \xi)} - \frac{V_E^2}{\mu}\right]S_7\right\} \qquad \text{(A2)}$$

where $P = V_E L/D_E$, $\xi = (H_E + V_E)H_E/D_E$, $\beta = (V_E^2/4D_E + \mu)^{1/2}$, and

$$S_1 = \text{erfc}\,[V_E t/(4D_E t)^{1/2}]$$
$$S_2 = \text{erfc}\,[(L + V_E t)/(4D_E t)^{1/2}]$$
$$S_3 = \exp(\xi t)\,\text{erfc}\,[(V_E + 2H_E)t/(4D_E t)^{1/2}]$$
$$S_4 = \exp(\xi t + H_E L/D_E)\,\text{erfc}\,[(L + (V_E + 2H_E)t)/(4D_E t)^{1/2}]$$
$$S_5 = \text{erfc}\,[L/(4D_E t)^{1/2} - \beta(t)^{1/2}]$$
$$S_6 = \text{erfc}\,[L/(4D_E t)^{1/2} + \beta(t)^{1/2}]$$
$$S_7 = \text{erf}\,[\beta(t)^{1/2}]$$

The cumulative volatilization $V_{cb}(t)$ of a chemical initially incorporated between L and $L+W$ is

$$V_c^b(t) = V_c(t; L + W) - V_c(t; L) \qquad \text{(A3)}$$

Details of the derivation of (A2) are available upon request.

Appendix B

As shown by *Jury et al.* [1984*a*], compounds with large K_H are insensitive to the thickness of the boundary layer. Therefore the volatilization solution (18) with $H_E \to \infty$ will describe the behavior of these compounds adequately. For the case of zero water evaporation ($V_E = 0$) and zero boundary layer thickness ($H_E \to \infty$), (18) becomes

$$J_s = C_o e^{-\mu t}(D_E/\pi t)^{1/2}[1 - \exp(-L^2/4D_E t)] \qquad \text{(B1)}$$

where the approximation

$$\text{erfc}\,[x] = \frac{1}{(\pi)^{1/2}}\frac{e^{-x^2}}{x} \qquad \text{(B2)}$$

has been used to expand the error function for large x [*Carslaw and Jaeger*, 1959].

Thus the volatilization flux from a buried layer of chemical located initially between $z = L$ and $z = L + W$ is

$$J_s^b = -C_o e^{-\mu t}(D_E/\pi t)^{1/2}(\exp(-L^2/4D_E t) - \exp[-(L + W)^2/4D_E t]) \qquad \text{(B3)}$$

The total mass fraction $V_c^b(\infty)/M_o$ volatilized in infinite time is then

$$V_c^b(\infty)/M_o = \frac{1}{W}\int_0^\infty \left(\frac{D_E}{\pi t}\right)^{1/2} \exp(-\mu t) \cdot \{\exp(-L^2/4D_E t) - \exp[-(L + W)^2/4D_E t]\}\, dt \qquad \text{(B4)}$$

where $M_o = C_o W$ is the initial mass.

If we make the substitution $y = t^{1/2}$, (B4) becomes

$$V_c^b(\infty)/M_o = \frac{2}{W}\left(\frac{D_E}{\pi}\right)^{1/2}\int_0^\infty \exp(-\mu y^2)\{\exp(-L^2/4D_E y^2) - \exp[-(L + W)^2/4D_E y^2]\}\, dy \qquad \text{(B5)}$$

Making use of the well known definite integral

$$\int_0^\infty \exp(-ay^2 - b/y^2)\, dy = \tfrac{1}{2}(\pi/a)^{1/2} \exp[-2(ab)^{1/2}] \quad \text{(B6)}$$

[*Abramowitz and Stegan*, 1970], (B5) becomes

$$\frac{V_c^b(\infty)M}{M_o} = \frac{1}{W}\left(\frac{D_E}{\mu}\right)^{1/2}$$

$$\cdot \exp[-L(\mu/D_E)^{1/2}][\{1 - \exp[-W(\mu/D_E)^{1/2}]\} \quad \text{(B7)}$$

which approaches

$$\frac{V_c^b(\infty)M}{M_o} = e^{-L(\mu/D_E)^{1/2}} \quad \text{(B8)}$$

for small W. Hence the fractional cumulative volatilization loss of chemical in a narrow band a distance L below the surface is given by (B8). Thus to minimize $V_c^b(\infty)/M_o$,

$$L \gg (D_E/\mu)^{1/2} \quad \text{(B9)}$$

Values of $L = 5(D_E/\mu)^{1/2}$, which lower $V_c^b(\infty)/M_o$ to 0.007, are calculated in the text as examples of the limiting soil cover. Equation (B9) will underestimate the mass loss when evaporation is present.

Acknowledgment. The authors would like to thank the California Department of Health Services for financial support of the research discussed in this project.

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(Received November 16, 1988;
revised July 12, 1989;
accepted July 20, 1989.)

WATER RESOURCES RESEARCH, VOL. 28, NO. 2, PAGES 607–608, FEBRUARY 1992

Correction to "Evaluation of Volatilization by Organic Chemicals Residing Below the Soil Surface" by William A. Jury, David Russo, Gary Streile, and Hesham El Abd

In the paper "Evaluation of Volatilization by Organic Chemicals Residing Below the Soil Surface" by William A. Jury et al. (*Water Resources Research*, *26*(1), 13–20, 1990), some of the Henry's constants or degradation half-lives that were used in making evaluations of several chemicals are either inaccurate or wrong. We have corrected these values using recent information from literature compilations [*Howard*, 1990; *Howard et al.*, 1991; *Lyman et al.*, 1990] that were not available at the time the original paper was written.

Results

Table 1 shows modified chemodynamic properties for the five chemicals we felt should be reevaluated. Three of the compounds (acrolein, chloroethene and xylene) had erroneous Henry's constant values in the original publication. Since the new values differ signifcantly from the former ones, none of the screening model calculations for these compounds in the earlier paper are valid. The compounds have also been assigned half-lives using the range of values recommended by *Howard et al.* [1991]. With the exception of chloroethene (vinyl chloride), the compounds are believed to degrade rapidly in soil. However, *Ryan et al.* [1988] classified chloroethene as rapidly degrading (half-life of less than 10 days). These new chemodynamic properties will be used below to recalculate the information for Tables 3 and 4 of the original paper.

Table 3 calculates the percent loss of each compound by volatilization after 1 year of incorporation under 1 m of sandy or clayey soil cover (properties summarized in Table 2 of the original paper). With the modified values, none of the compounds are evaluated to lose significant mass under the clayey soil cover, and acrolein, toluene and benzene are also shielded against significant loss by the sandy soil cover. These conclusions differ from ones drawn in the original study.

Table 4 summarizes the thickness of soil cover required to restrict volatilization losses to less than 0.7% of initial mass for each of the five compounds. In contrast to the conclusions drawn in the original evaluation, acrolein is now shielded from loss by relatively shallow sandy and clayey layers. Benzene requires significantly less cover thickness than in the original paper because a shorter half-life is used here.

Discussion

The modified calculations and their implications shown above point out how important it is to have accurate values for the chemodynamic properties of compounds evaluated by a volatilization screening model. Standardized protocols for the determination of Henry's constant and organic C partitioning coefficients have reduced the uncertainties of these properties [*Lyman et al.*, 1990], but the degradation coefficients of volatile organic compounds remain highly variable. Most information on degradation of these compounds has come from aquatic studies and not direct evaluation in unsaturated soil [*Howard et al.*, 1991; *Lyman et al.*, 1990]. Extrapolation of rate constants from one medium to another is difficult, because there are two contrasting effects of reducing the water content. First, oxygen replenishment of the water phase is rendered more efficient, which could increase the efficiency of microbiological breakdown of the compound. Second, the volume fraction where degradation is occurring is decreasing proportionally to the water content, which will decrease the apparent degradation rate constant evaluated on a soil volume basis. The latter effect could lead to a significantly longer half-live for volatile organic compounds diffusing in soil with a low water content. More research clearly is needed on degradation of volatile compounds during transport in unsaturated soil.

TABLE 1. Chemodynamic Fate Properties of Volatile Organic Compounds Used in the Simulations

Compound	K_{oc},* cm^3 g^{-1}	K_H†	$t_{1/2}$,‡ days
Acrolein	24	0.0028	7–30
Benzene	80	0.22	5–16
Chloroethene	56	0.44	30–180
Toluene	98	0.28	4–22
Xylene	50	0.28	7–30

*Data from *Howard* [1990].
†Acrolein value from *Ryan et al.* [1988]; other values from *Howard* [1990].
‡Data from *Howard et al.* [1991].

Paper number 91WR02930.
0043-1397/92/91WR-02930$02.00

TABLE 3. Volatilization Losses (in Percent) After 1 Year Under a 1-m Soil Cover

Compound	Sandy Soil	Clayey Soil
Acrolein	≈0	≈0
Benzene	0.1–1.6	≈0
Chloroethene	16.3–44.5	0.1–0.7
Toluene	0.1–3.5	≈0
Xylene	1.0–10.8	≈0

TABLE 4. Soil Cover Thickness (Centimeters) Required to Restrict Volatilization to Less Than 0.7% of Mass Incorporated Into Soil

Compound	Sandy Soil	Clayey Soil
Acrolein	1–34	5–10
Benzene	76–136	15–27
Chloroethene	295–720	59–145
Toluene	70–164	14–32
Xylene	120–249	24–50

Acknowledgments. The authors express appreciation to Thomas Overcamp of Clemson University and to William Spencer of the U.S. Department of Agriculture, Riverside for pointing out errors in the chemodynamic properties of several compounds in the original paper, and for suggesting modifications and additional sources of information.

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(Received October 3, 1991.)

APPENDIX A.4

LINEAR PARTITIONING (SUMMERS) MODEL RESULTS

TABLE A-4-1
SUMMERS MODEL RESULTS
FEASIBILITY STUDY
BADGER ARMY AMMUNITION PLANT

COMPOUND	PAL µg/L	PROPELLANT BURNING GROUNDS												DETERRENT BURNING GROUND	
		LANDFILL 1		1949 WASTE PIT		BURN AREA/PITS		RACETRACK						DBG	
		DAF	TARGET	DAF	TARGET	DAF	TARGET	DAF			TARGET			DAF	TARGET
ORGANICS															
BEHP	0.3					4.47	955 ppb	2.62			434 ppb			6.7	1734 ppb
Vinyl Chloride	0.0015					6.79	0.0047	2.62			0.0011			6.7	0.0045
Benzene	0.067					6.79	1.6	2.62			0.39			6.7	1.6
Carbon Tetrachloride	0.5					6.79	49	2.62			12			6.7	48
Chloroform	0.6					6.79	61	2.62			15			6.7	60
1,2-dichloroethane	0.05					6.79	0.4	2.62			0.1			6.7	0.4
2,4-DNT	0.005					4.47	0.056	2.62			0.025			6.7	0.10
2,6-DNT	0.005					4.47	0.066	2.62			0.030			6.7	0.12
Toluene	68.6					6.79	84,419	2.62			20,723			6.7	82,774
2-butanone	90.0					6.79	4,122	2.62			1,012			6.7	4,041
naphthalene	8.0					4.47	9,065	2.62			4,406			6.7	17,597
1,1,1-trichloroethane	40.0					6.79	21,607	2.62			5,304			6.7	21,186
1,1,2-trichloroethane	0.06					6.79	0.8	2.62			0.2			6.7	0.8
trichloroethene	0.18					53.1	184	2.62			2.2			6.7	8.7
METALS								W	NE	SE	W	NE	SE		
Arsenic	5	7.95	266 ppb	2.02	67.7 ppb	2.74	91.8 ppb	2.39	5.63	6.79	80	189	227		
Barium	200	7.95	-	2.02	-	2.74	-	2.39	5.63	6.79	-	-	-		
Cadmium	1	7.95	53.2	2.02	13.5	2.74	18.4	2.39	5.63	6.79	16	38	45		
Chromiun	5	7.95	6,558	2.02	1,666	2.74	36,100	2.39	5.63	6.79	31,488	74,175	89,458		
Iron	150	7.95	65,588	2.02	16,665	2.74	22,605	2.39	5.63	6.79	19,718	46,447	56,018		
Mercury	0.2	7.95	-	2.02	-	2.74	-	2.39	5.63	6.79	-	-	-		
Manganese	25	7.95	29,812	2.02	7,575	2.74	10,275	2.39	5.63	6.79	8,962	21,112	25,462		
Lead	5	7.95	3,935	2.02	1,000	2.74	72,747	2.39	5.63	6.79	6,345	14,948	18,027		
Selenium	1	7.95	21.5	2.02	5.5	2.74	7.4	2.39	5.63	6.79	6.4	15.2	18.3		
Zinc	2,500	7.95	318,000	2.02	80,800	2.74	109,600	2.39	5.63	6.79	95,600	225,200	271,600		

TABLE A-4-1 (CONTINUED)
SUMMERS MODEL RESULTS
FEASIBILITY STUDY
BADGER ARMY AMMUNITION PLANT

COMPOUND	PAL µg/L	ROCKET PASTE AREA				SETTLING PONDS/SDA				SETTLING PONDS		SETTLING PONDS/SDA	
		STREAM		DITCHES		FINAL CREEK (NS)		FINAL CREEK (EW)		PONDS		SDA	
		DAF	TARGET	DAF	TARGET	DAF	TARGET	DAF	TARGET	DAF	TARGET	DAF	TARGET
ORGANICS													
BEHP	0.3			2.35	370 ppb	1.39	170 ppb	140	153,510 ppb	2.22	340 ppb	3.90	781 ppb
Vinyl Chloride	0.0015			2.35	0.00097	1.39	0.00045	140	0.4	2.22	0.000897	3.90	0.00206
Benzene	0.067			2.35	0.33	1.39	0.154	140	139	2.22	0.307	3.90	0.705
Carbon Tetrachloride	0.5			2.35	10.3	1.39	4.73	140	4,261	2.22	9.44	3.90	21.7
Chloroform	0.6			2.35	12.8	1.39	5.92	140	5,336	2.22	11.8	3.90	27.1
1,2-dichloroethane	0.05			2.35	0.0908	1.39	0.0418	140	37.6	2.22	0.0835	3.90	0.192
2,4-DNT	0.005			2.35	0.0216	1.39	0.010	140	9.0	2.22	0.0199	3.90	0.0457
2,6-DNT	0.005			2.35	0.0254	1.39	0.012	140	10.5	2.22	0.0234	3.90	0.0536
Toluene	68.6			2.35	17,652	1.39	8,136	140	7,326,107	2.22	16,231	3.90	37,262
2-butanone	90.0			2.35	862	1.39	397	140	357,698	2.22	792	3.90	1,819
naphthalene	8.0			2.35	3,512	1.39	1,619	140	1,457,521	2.22	3,229	3.90	7,413
1,1,1-trichloroethane	40.0			2.35	4,518	1.39	2,082	140	1,875,121	2.22	4,154	3.90	9,538
1,1,2-trichloroethane	0.06			2.35	0.169	1.39	0.078	140	70.1	2.22	0.155	3.90	0.356
trichloroethene	0.18			2.35	1.85	1.39	0.854	140	769	2.22	1.7	3.90	3.91
METALS													
Arsenic	5	1.21	40.5 ppb	2.35	78.7 ppb	1.39	46.6 ppb	140	4,690 ppb	2.22	74.4 ppb	3.90	131 ppb
Barium	200	1.21	-	2.35	-	1.39	-	140	-	2.22	-	3.90	-
Cadmium	1	1.21	8.1	2.35	15.7	1.39	9.3	140	938	2.22	14.9	3.90	26.1
Chromiun	5	1.21	2,517	2.35	4,888	1.39	2,891	140	291,200	2.22	4,618	3.90	8,112
Iron	150	1.21	9,982	2.35	19,388	1.39	11,468	140	1,155,000	2.22	18,315	3.90	32,175
Mercury	0.2	1.21	-	2.35	-	1.39	-	140	-	2.22	-	3.90	-
Manganese	25	1.21	4,538	2.35	8,812	1.39	5,212	140	525,000	2.22	8,325	3.90	14,625
Lead	5	1.21	3,854	2.35	7,485	1.39	688	140	69,300	2.22	1,099	3.90	1,948
Selenium	1	1.21	3.3	2.35	1.3	1.39	3.8	140	378	2.22	6	3.90	10.5
Zinc	2,500	1.21	48,400	2.35	94,000	1.39	55,600	140	5,600,000	2.22	88,800	3.90	156,000

APPENDIX A.5

TRANSPORT (JURY) MODEL RESULTS

TABLE A-5-1
JURY MODEL RESULTS
FEASIBILITY STUDY
BADGER ARMY AMMUNITION PLANT

COMPOUND	PAL µg/L	PROPELLANT BURNING GROUND: SURFICIAL, SOIL/RACETRACK		SURFICIAL SOIL/PITS		SUBSURFACE 0'-20'		SUBSURFACE 20'-40'		SUBSURFACE 40'-60'	
		DAF	TARGET	DAF	TARGET	DAF	TARGET	DAF	TARGET	DAF	TARGET
ORGANICS											
BEHP	0.3	1.7(10^8)	7.9(10^8) ppb	1.7(10^8)	1.35(10^9) ppb	1.7(10^8)	1.35(10^9) ppb	(1)	-	(1)	-
Vinyl Chloride	0.0015	(1)	-	(1)	-	(1)	-	(1)	-	(1)	-
Benzene	0.067	>2.3(10^8)	>3.4(10^6) ppb	>2.3(10^8)	>8.7(10^6) ppb	(3)	-	(3)	-	(3)	-
Carbon Tetrachloride	0.5	(1)	-	(1)	-	(1)	-	(1)	-	(1)	-
Chloroform	0.6	(1)	-	(1)	-	(1)	-	(1)	-	(1)	-
1,2-dichloroethane	0.05	(1)	-	(1)	-	(1)	-	(1)	-	(1)	-
2,4-DNT	0.005	9.4(10^7)	55,000 ppb	9.4(10^7)	95,000 ppb	2.18(10^6)	2,180 ppb	1.18(10^5)	118 ppb	6,367	6.4 ppb
2,6-DNT	0.005	>2.24(10^8)	>270,000 ppb	>2.24(10^8)	>460,000 ppb	>2.24(10^{12})	>4.5(10^9) ppb	1.24(10^{11})	248,000,000	1.12(10^8)	224,000
Toluene	68.6	(1)	-	(1)	-	(2)	-	(2)	-	(2)	-
2-butanone	90.0	(1)	-	(1)	-	(1)	-	(1)	-	(1)	-
naphthalene	8.0	(1)	-	(1)	-	(1)	-	(1)	-	(1)	-
1,1,1-trichloroethane	40.0	(1)	-	(1)	-	(1)	-	(1)	-	(1)	-
1,1,2-trichloroethane	0.06	(1)	-	(1)	-	(1)	-	(1)	-	(1)	-
trichloroethene	0.18	(1)		(1)	-	1.3(10^7)	1.56(10^7) ppb	5.7(10^5)	686,280	2.35(10^4)	28,294
METALS			W								
Arsenic	5	~1	80 ppb	~1	91.8 ppb	-	-	-	-	-	-
Barium	200	-	-	-	-	-	-	-	-	-	-
Cadmium	1	(1)	-	(1)	-	-	-	-	-	-	-
Chromiun	5	~1	31,488 ppb	~1	36,100 ppb	-	-	-	-	-	-
Iron	150	(1)	-	(1)	-	-	-	-	-	-	-
Mercury	0.2	-	-	-	-	-	-	-	-	-	-
Manganese	25	(1)	-	(1)	-	-	-	-	-	-	-
Lead	5	~1	6,345 ppb	~1	72,747 ppb	-	-	-	-	-	-
Selenium	1	~1	6.4 ppb	~1	7.4 ppb	-	-	-	-	-	-
Zinc	2,500	~1	95,600 ppb	~1	109,600 ppb	-	-	-	-	-	-

LEGEND:
- (1) Not a contaminant of concern for this setting/depth.
- (2) Eliminated by screening model.
- (3) Screened out at lower level with Jury model.
- ~ Not Run

NOTES:
- (a) DAF represents attenuation in soil column.
- (b) Few runs for Jury model for metals indicated no significant difference from screening model. No further runs for metals made.
- (c) Subsurface at PBG refers to burn pits.
- (d) Screened out at lower level with Jury model.

TABLE A-5-1 (CONTINUED)
JURY MODEL RESULTS
FEASIBILITY STUDY
BADGER ARMY AMMUNITION PLANT

COMPOUND	PAL µg/L	PBG (CONT.) - BURN PITS				DETERRENT BG		ROCKET PASTE AREA		SETTLING PONDS	
		SUBSURFACE 60'-80'		SUBSURFACE 80'-100'		SURFICIAL SOIL		SURFICIAL SOIL		POND SEDIMENTS	
		DAF	TARGET	DAF	TARGET	DAF	TARGET	DAF	TARGET	DAF	TARGET
ORGANICS											
BEHP	0.3	(1)	-	(1)	-	>1.7(10^8)	>2(10^9) ppb	(1)	-	>1.7(10^8)	>6.7(10^8) ppb
Vinyl Chloride	0.0015	(1)	-	(1)	-	(1)	-	(1)	-	(1)	-
Benzene	0.067	(3)	-	>2.3(10^8)	>8,694,000 ppb	>2.3(10^8)	>8.6(10^6) ppb	(1)	-	(1)	-
Carbon Tetrachloride	0.5	(1)	-	(1)	-	(1)	-	(1)	-	(1)	-
Chloroform	0.6	(1)	-	(1)	-	(1)	-	(1)	-	(1)	-
1,2-dichloroethane	0.05	(1)	-	(1)	-	(1)	-	(1)	-	(1)	-
2,4-DNT	0.005	336.4	0.336 ppb	16.4	0.0164 ppb	55,754	84 ppb	1.75(10^7)	9,253 ppb	10,524	5.25 ppb
2,6-DNT	0.005	1.28(10^5)	256 ppb	114.4	0.229 ppb	>2.24(10^8)	>690,368 ppb	>2.24(10^8)	242,144 ppb	7.5(10^7)	76,284 ppb
Toluene	68.6	(2)	-	(2)	-	(1)	-	(1)	-	(1)	-
2-butanone	90.0	(1)	-	(1)	-	(1)	-	(1)	-	(1)	-
naphthalene	8.0	(1)	-	(1)	-	(1)	-	(1)	-	(1)	-
1,1,1-trichloroethane	40.0	(1)	-	(1)	-	(1)	-	(1)	-	(1)	-
1,1,2-trichloroethane	0.06	(1)	-	(1)	-	(1)	-	(1)	-	(1)	-
trichloroethene	0.18	912	1,098 ppb	30.4	36.6 ppb	(1)	-	(1)	-	(1)	-
METALS											
Arsenic	5	-	-	-	-	-	-	-	-	-	-
Barium	200	-	-	-	-	-	-	-	-	-	-
Cadmium	1	-	-	-	-	-	-	-	-	-	-
Chromiun	5	-	-	-	-	-	-	-	-	-	-
Iron	150	-	-	-	-	-	-	-	-	-	-
Mercury	0.2	-	-	-	-	-	-	-	-	-	-
Manganese	25	-	-	-	-	-	-	-	-	-	-
Lead	5	-	-	-	-	-	-	-	-	-	-
Selenium	1	-	-	-	-	-	-	-	-	-	-
Zinc	2,500	-	-	-	-	-	-	-	-	-	-

LEGEND:
(1) Not a contaminant of concern for this setting/depth.
(2) Eliminated by screening model.
(3) Screened out at lower level with Jury model.
~ Not Run

NOTES:
(a) DAF represents attenuation in soil column.
(b) Few runs for Jury model for metals indicated no significant difference from screening model. No further runs for metals made.
(c) Subsurface at PBG refers to burn pits.
(d) Screened out at lower level with Jury model.

TABLE A-5-1 (CONTINUED)
JURY MODEL RESULTS
FEASIBILITY STUDY
BADGER ARMY AMMUNITION PLANT

COMPOUND	PAL µg/L	SETTLING PONDS/SDA					
		SDA		FINAL CREEK NS SECT.		FINAL CREEK EW SECT.	
		DAF	TARGET	DAF	TARGET	DAF	TARGET
ORGANICS							
BEHP	0.3	>1.7(10^8)	>1.2(10^9) ppb	>1.7(10^8)	>4.2(10^8) ppb	>1.7(10^8)	>4.2(10^{10}) ppb
Vinyl Chloride	0.0015	(1)	-	(1)	-	(1)	-
Benzene	0.067	(1)	-	(1)	-	(1)	-
Carbon Tetrachloride	0.5	(1)	-	(1)	-	(1)	-
Chloroform	0.6	(1)	-	(1)	-	(1)	-
1,2-dichloroethane	0.05	(1)	-	(1)	-	(1)	-
2,4-DNT	0.005	10,524	9.2 ppb	10,524	3.3 ppb	10,524	331 ppb
2,6-DNT	0.005	7.47(10^7)	134,012 ppb	7.47(10^7)	47,763 ppb	7.47(10^7)	4,810,700 ppb
Toluene	68.6	(1)	-	(1)	-	(1)	-
2-butanone	90.0	(1)	-	(1)	-	(1)	-
naphthalene	8.0	(1)	-	(1)	-	(1)	-
1,1,1-trichloroethane	40.0	(1)	-	(1)	-	(1)	-
1,1,2-trichloroethane	0.06	(1)	-	(1)	-	(1)	-
trichloroethene	0.18	(1)	-	(1)	-	(1)	-
METALS							
Arsenic	5	-	-	-	-	-	-
Barium	200	-	-	-	-	-	-
Cadmium	1	-	-	-	-	-	-
Chromiun	5	-	-	-	-	-	-
Iron	150	-	-	-	-	-	-
Mercury	0.2	-	-	-	-	-	-
Manganese	25	-	-	-	-	-	-
Lead	5	-	-	-	-	-	-
Selenium	1	-	-	-	-	-	-
Zinc	2,500	-	-	-	-	-	-

LEGEND:
(1) Not a contaminant of concern for this setting/depth.
(2) Eliminated by screening model.
(3) Screened out at lower level with Jury model.
~ Not Run

NOTES:
(a) DAF represents attenuation in soil column.
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(c) Subsurface at PBG refers to burn pits.
(d) Screened out at lower level with Jury model.

APPENDIX B

REMEDIAL TECHNOLOGY HANDBOOK

REMEDIAL INVESTIGATION/FEASIBILITY STUDY
BADGER ARMY AMMUNITION PLANT
BARABOO, WISCONSIN

REMEDIAL TECHNOLOGY HANDBOOK

DATA ITEM A009

CONTRACT DAAA15-91-D-0008

U.S. ARMY TOXIC AND HAZARDOUS MATERIALS AGENCY
ABERDEEN PROVING GROUND, MARYLAND

SEPTEMBER, 1992

Printed on recycled paper

REMEDIAL INVESTIGATION/FEASIBILITY STUDY
BADGER ARMY AMMUNITION PLANT

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CONTRACT DAAA15-91-D-0008
TASK ORDER 1

Prepared for:

United States Army
Toxic and Hazardous Materials Agency
Aberdeen Proving Ground, Maryland

Prepared by:

ABB Environmental Services
Portland, Maine
Project No. 6853-09

SEPTEMBER 1992

BADGER ARMY AMMUNITION PLANT
REMEDIAL TECHNOLOGY HANDBOOK

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1.0 INTRODUCTION

This Remedial Technology Handbook (RTH) identifies and describes potentially applicable remedial technologies for contaminated soil, sediment, surface water, and groundwater at the Badger Army Ammunition Plant (BAAP) site in Baraboo, Wisconsin.

1.1 SITE BACKGROUND

BAAP is a 7,354-acre industrial installation in Sauk County, Wisconsin, near the city of Baraboo. BAAP has had three active production periods since its construction in 1942: World War II (1943 to 1945), the Korean Conflict (1951 to 1953), and the Vietnam Conflict (1966 to 1975). During these periods, various formulations of propellants, including nitrocellulose (NC), rocket paste, nitroglycerine (NG), and smokeless powder were produced. During active industrial periods of operation, various chemicals and refuse materials associated with propellant manufacturing operations were disposed of at various sites on the installation. Chemical wastes of concern include NG, NC, acids, dinitrotoluenes (DNTs), diphenylamine, and various production and cleaning solvents. Previous investigations documented that these chemicals exist in the soils and groundwater at BAAP. In March 1975, plant operation was terminated and placed on standby status.

Investigations by Ayres Associates (Ayres), Envirodyne Engineers, Inc. (Envirodyne), Foth & Van Dyke Industrial, Inc. (Foth & Van Dyke), Olin Corporation (Olin), R.F. Sarko and Associates, Inc. (Sarko), Warzyn Engineering, Inc. (Warzyn), and others identified 11 potential hazardous waste sites requiring further investigation. All of these sites were investigated by ABB Environmental Services, Inc. (ABB-ES) during the remedial investigation: (1) Propellant Burning Ground, including Landfill 1, (2) Deterrent Burning Ground, (3) Existing Landfill, (4) Settling Ponds and Spoils Disposal Area, (5) Ballistics Pond, (6) Oleum Plant and Pond, (7) Nitroglycerine Pond, (8) Rocket Paste Area, (9) Old Acid Area, (10) New Acid Area, and (11) Old Fuel Oil Tank.

A preliminary evaluation was conducted to determine whether listed or characteristic Resource Conservation and Recovery Act (RCRA) wastes exist at any of the sites. The Master Environmental Plan mentioned that the only potassium (K) waste produced would be K044, a wastewater treatment sludge resulting from the

manufacture of explosives (Tsai et al., 1988). However, because the base is now on standby status, this K waste would not be produced. The 24DNT-, 26DNT-, and NG-contaminated soils found at some of the sites may qualify as listed wastes (i.e., U105, U106, and P081, respectively). Lead was detected in soil at levels in excess of the threshold for the Toxicity Characteristic Leaching Procedure (TCLP). These RCRA-listed and characteristic wastes would be subject to Land Disposal Restrictions (i.e., RCRA Subchapter I, Part 268) if placement of the wastes occurs. The applicability of Land Disposal Restrictions is evaluated for each alternative in the detailed analysis portion of the feasibility study (FS) report.

Certain Applicable or Relevant and Appropriate Requirements (ARARs) may pertain to each technology discussed in this handbook. These ARARs are listed in the ARARs handbook (ABB-ES, 1992). The ability of a remedial alternative to satisfy ARARs requirements will be discussed in the detailed analysis of alternatives in the FS report.

1.2 Scope and Purpose

The information in this report serves as a primary resource for conducting the BAAP FS. For each site, the FS summarizes site contamination and establishes remedial objectives. This handbook provides information about available remedial technologies for soil and groundwater to assist the decision-maker in selecting a protective and appropriate remedy for each site at BAAP.

This handbook describes potentially applicable technologies for BAAP on the basis of three broad categories: effectiveness, implementability, and cost. For purposes of technology evaluation, these categories were divided further into 12 evaluation criteria, which were designed in accordance with the revised National Contingency Plan effective March 1990, and the Superfund Amendments and Reauthorization Act of October 1986.

Technologies presented in this handbook were chosen from a preliminary list of technologies identified and determined to be potentially applicable to attaining BAAP response objectives. Technologies identified for soil/sediment and water (including groundwater), with a brief description of each technology, are listed in Appendix A, Table A-1. The technologies were screened by evaluating technical implementability at BAAP. Technologies that cannot be implemented at BAAP because of site and waste characteristics were eliminated from further consideration

and are not included in this RTH. For example, soil flushing was eliminated as a treatment technology for soils because it is primarily used for removal of water-soluble compounds; soils investigated at BAAP are contaminated with compounds of limited solubility. The technologies, site- and waste-limiting characteristics, and screening status (i.e., retained or eliminated from further evaluation) are listed in Appendix A, Table A-2.

This document consists of four sections. Section 2.0 discusses the remedy evaluation criteria listed in the U.S. Environmental Protection Agency's (USEPA) Guidance for Conducting Remedial Investigations and Feasibility Studies (USEPA, 1988). Sections 3.0 and 4.0 describe remedial technologies for soil/sediment and water treatment, respectively. Technologies in each category are discussed in separate subsections, each including a qualitative description of the technology and a detailed evaluation. A summary table at the end of each subsection presents conclusions about the applicability of each technology for use at BAAP.

2.0 REMEDIAL TECHNOLOGY EVALUATION CRITERIA

Twelve criteria were developed to address technical factors likely to be important for selecting remedial actions (Figure 2-1). Evaluation criteria encompass technical, cost, and institutional considerations (USEPA, 1988). Specific criteria used to evaluate remedial technologies are summarized in Table 2-1. These evaluation criteria assist in selecting an appropriate remedial action at each site. The following subsections describe the 12 evaluation criteria.

2.1 EFFECTIVENESS ASSESSMENT

Four specific evaluation criteria comprise the effectiveness assessment: (1) expected reduction in mobility, toxicity, and volume, (2) treatment time, (3) potential impact to public health or the environment, and (4) secondary waste management requirements.

2.1.1 Reduction in Mobility, Toxicity, and Volume

Treatment methods may be employed to reduce principal threats at a site through destruction of toxic contaminants, reduction in the mass of contaminants, reduction in contaminant mobility, or reduction in the volume of contaminated media. This criterion focuses on the effectiveness of treatment processes in reducing the mobility, toxicity, or volume of contaminants.

2.1.2 Treatment Time

Throughput rates, process feed rates, required engineering design, technology development, mobilization, start-up, and demobilization affect the time needed to achieve remedial objectives. This criterion highlights major factors pertaining to process flow and treatment time.

2.1.3 Potential Impact to Public Health and the Environment

Potential adverse impacts or safety concerns may be associated with certain technologies. This criterion addresses potential impacts that may result from implementing a technology, and identifies effective available mitigative measures to reduce adverse impact.

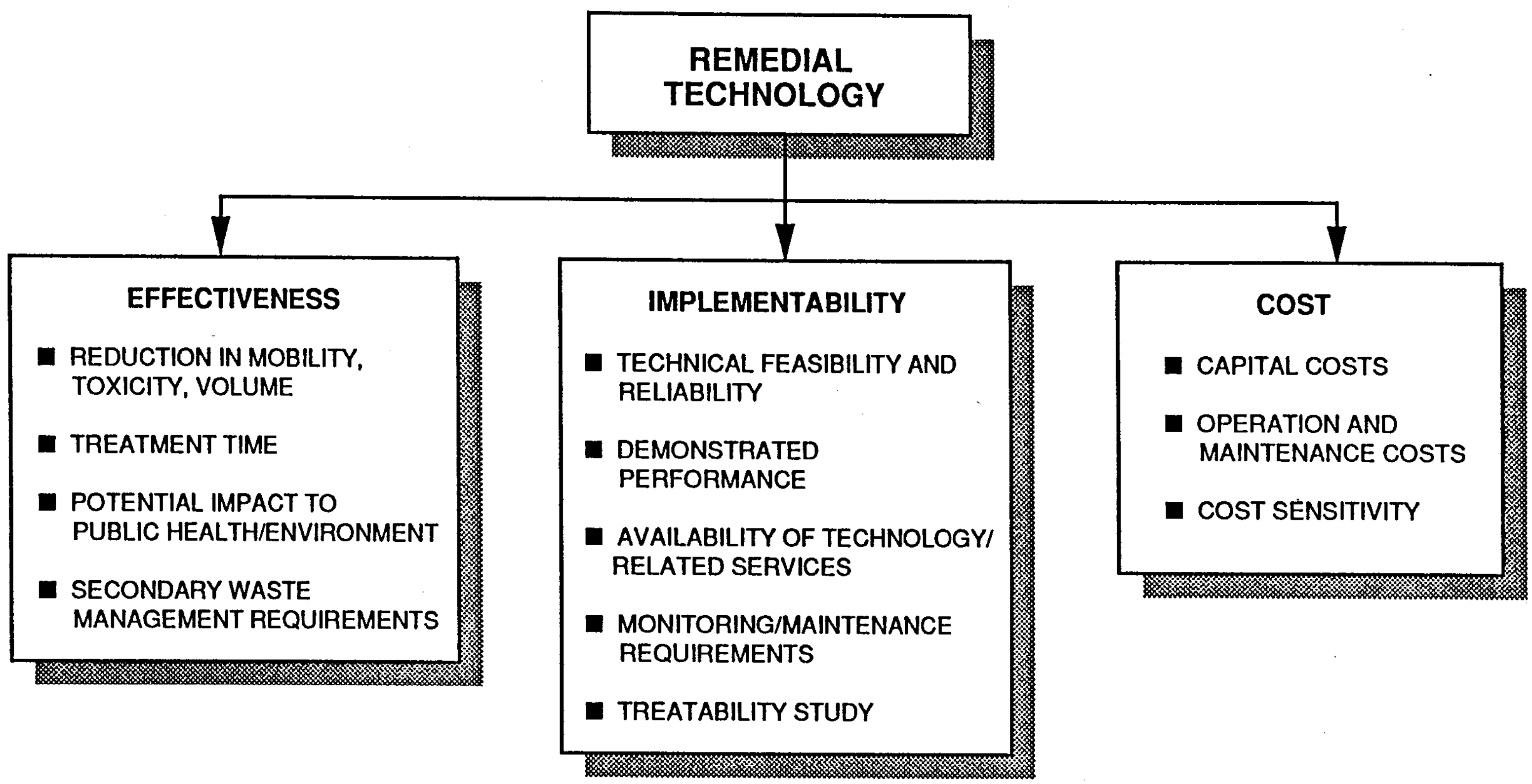


FIGURE 2-1
REMEDIAL TECHNOLOGY EVALUATION CRITERIA
REMEDIAL TECHNOLOGY HANDBOOK
BADGER ARMY AMMUNITION PLANT
ABB Environmental Services, Inc.

9007068D

TABLE 2-1
TECHNOLOGY EVALUATION CRITERIA

REMEDIAL TECHNOLOGY HANDBOOK
BADGER ARMY AMMUNITION PLANT

EFFECTIVENESS

Reduction in Mobility, Toxicity, and Volume
- effectiveness of the treatment processes in reducing mobility, toxicity, or volume of contaminants

Treatment Time
- process feed rates and required installation times associated with the technology

Potential Impact to Public Health/Environment
- potential adverse impacts or safety concerns associated with technology implementation

Secondary Waste Management Requirements
- type and quantity of residuals remaining after treatment

IMPLEMENTABILITY

Technical Feasibility and Reliability
- applicability of the technology for particular contaminants
- reliability of the technology

Demonstrated Performance
- level of technological development
- specific sites where technology has been applied

Availability of Technology and Related Services
- commercial availability of necessary equipment and specialists
- commercial vendors and manufacturers marketing technology

Monitoring and Maintenance Requirements
- monitoring and maintenance requirements associated with the technology during remedial action

Treatability Study
- need for treatability studies to demonstrate effectiveness of the technology for evaluation during detailed analysis in the BAAP FS.

COST

Capital Cost
- capital expenditures associated with the technology

Operation and Maintenance Costs
- costs required to effectively operate and maintain technology throughout remedial action

Cost Sensitivity
- factors likely to impact technology cost estimates

Notes:
BAAP - Badger Army Ammunition Plant
FS - Feasibility Study

2.1.4 Secondary Waste Management Requirements

Process residuals may require waste management or appropriate disposal to minimize environmental or public health threats. This criterion identifies the type and quantity of residuals remaining after treatment and identifies disposal and treatment options for residuals.

2.2 IMPLEMENTABILITY ASSESSMENT

In a broad manner, the implementability assessment considers the technical feasibility of implementing a technology for particular contaminants and its ability to reliably meet specified performance goals. Five specific evaluation criteria comprise the implementability assessment.

2.2.1 Technical Feasibility and Reliability

This criterion focuses on the applicability of a technology to particular contaminants and its ability to reliably meet specified performance goals.

2.2.2 Demonstrated Performance

Increased costs may be associated with selecting unproven technologies. This criterion reviews the level of technological development and, where possible, lists specific sites where the technology has been applied.

2.2.3 Availability of Technology and Related Services

Readily available services and equipment will likely increase the ability to implement a technology. This criterion examines commercial availability and lists vendors marketing the technology.

2.2.4 Monitoring and Maintenance Requirements

Technologies requiring continuous or long-term operations necessitate systems capable of monitoring the effectiveness of treatment. This criterion identifies

primary monitoring and maintenance responsibilities associated with each technology.

2.2.5 Treatability Studies

This criterion identifies the need for treatability studies to demonstrate the effectiveness of the technology for evaluation during detailed analysis in the BAAP FS.

2.3 COST ASSESSMENT

Cost estimates in this handbook consider capital costs and operation and maintenance (O&M) costs. Cost sensitivities, important when selecting remedial technologies, are also described.

2.3.1 Capital Costs

Capital costs consist of direct and indirect costs, including expenditures initially incurred to develop, construct, and implement a remedial action. Direct costs include expenditures for the equipment, labor, and materials necessary to install remedial actions.

Indirect costs include expenditures for engineering, financial, and other services that are not part of actual installation activities, but are required to complete remedial actions.

2.3.2 Operation and Maintenance Costs

O&M costs refer to expenditures associated with power, labor, supplies, residual disposal requirements, and long-term post-construction costs (including equipment replacement costs) required to effectively operate and maintain the remedial action throughout its useful life.

2.3.3 Cost Sensitivity

Technology cost estimates are intended to reflect actual costs with an accuracy of -30 to +50 percent, as specified in the USEPA guidance. This criterion considers factors likely to impact those estimates.

3.0 SOIL AND SEDIMENT TREATMENT TECHNOLOGIES

The selection of an appropriate remedial technology depends on the physical characteristics, contaminant types, and contaminant concentrations for each site at BAAP. The FS report will summarize the nature and distribution of contaminants, remedial objectives, and associated contaminant volumes for each site. For the purposes of this RTH, general site characteristics may be summarized to identify a range of remedial technologies for soil and sediment at BAAP.

BAAP activities that have contaminated soil and sediment include the burning of solvents and solvent-containing solid wastes, along with propellants, explosives, and propellant-contaminated wastes. Other contamination was caused by the disposal of process wastewaters from manufacturing acids, ash, NC, NG, and propellant formulations. Individual areas at BAAP were sites for different steps of the manufacturing or disposal processes. Consequently, the characteristics of contamination vary at each area. Contaminated areas include burning areas, acid storage areas, holding ponds for backwash water, neutralization ponds, landfills, and drainage ditches.

Contaminant types and concentrations detected in soil and sediment during the remedial investigation varied greatly across the site. Predominant compounds identified in soils and sediment include metals, semivolatile organic compounds (SVOCs, including DNTs, which are propellant additives), nitrate/nitrite (NIT), sulfate (SO4), and NC.

Metals (especially lead [PB]) were detected at several sites in both surface and subsurface soils. Concentrations ranged from below detection limits to 10,000 milligrams per kilogram (mg/kg). Soils at isolated locations failed the Extraction Procedure (EP) Toxicity Test for PB. Preliminary risk assessments suggest that PB may pose much of the risk associated with surface soil at one of the sites.

The primary SVOC detected in surface and subsurface soils, identified as posing a potential health risk, is 24DNT. Concentrations of 24DNT in surface and subsurface soils ranged from below detection limits to 280,000 mg/kg. DNTs do not appear to present a direct health risk via ingestion; however, the soil may be acting as a contamination source to groundwater. Therefore, technologies to remediate 24DNT-contaminated soil were evaluated.

Other contaminants in soils that may pose a health concern are NIT, SO4, and NC. NIT concentrations in soil ranged from below detection limits to 4,300 mg/kg. S04 concentrations ranged from below detection limits to 14,000 mg/kg. At one site, NC was detected ranging from below detection limits to 60,000 mg/kg. NC releases NIT via chemical hydrolysis and/or biotransformation. A preliminary risk assessment indicates these contaminants do not pose a direct health risk via ingestion. Because contaminated soil may be acting as a source of contamination to groundwater, remedial technologies for these contaminants in soil were evaluated.

Given these site contamination characteristics, soil and sediment technologies were evaluated for technical, cost, and institutional considerations associated with potential remedial measures. Site-specific contamination assessments and remedial objectives are discussed in the FS report.

3.1 INCINERATION

This subsection discusses incineration technologies.

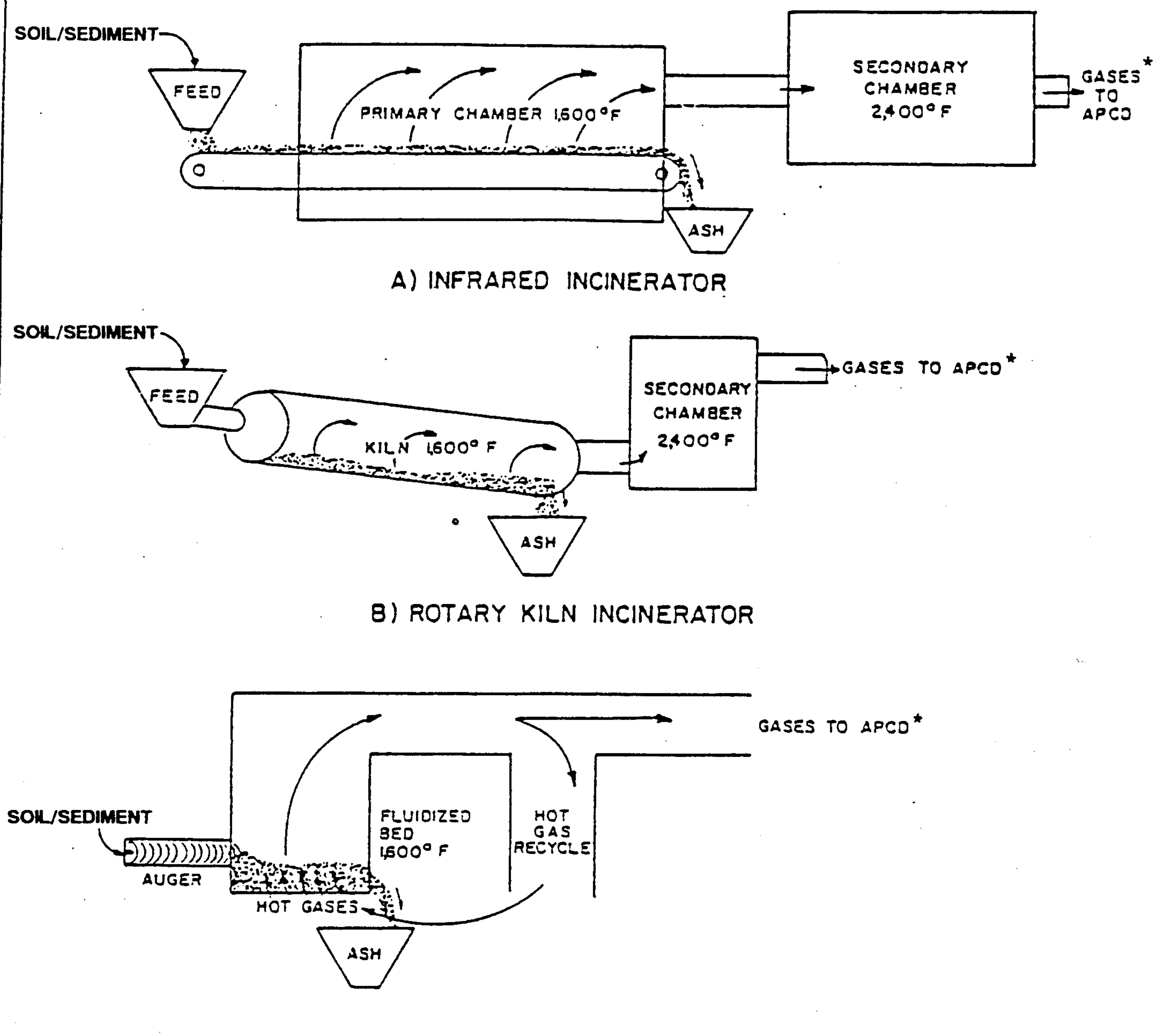
3.1.1 Description

Incineration technologies use high-temperature oxidation under controlled conditions to destroy organic constituents in liquid, gaseous, and solid wastestreams. Incineration can be performed either on-site using a mobile incinerator or off-site by transporting the waste to an operating hazardous waste incinerator.

<u>On-site Incineration</u>. Various proven technologies suitable for on-site incineration are on the market. Three types of combustion chamber configurations are available: rotary kiln, infrared, and fluidized bed (Figure 3-1). Technologies that have been demonstrated successfully at hazardous waste sites are described briefly in the following paragraphs.

<u>Infrared Incineration</u>. The infrared incinerator employs a two-stage combustion process (see Figure 3-1). These units decontaminate waste by passing it on a conveyor belt beneath infrared heating elements. This chamber is maintained at 1,600 to 1,800°F, and solids remain in the chamber for approximately 30 minutes.

Hazardous organics are volatilized and destroyed in a few seconds in the secondary combustion chamber, which operates in a flame mode at a temperature of 2,400°F.



* AIR POLLUTION CONTROL DEVICE

FIGURE 3-1
COMPARISON OF INCINERATION COMBUSTION CHAMBERS
REMEDIAL TECHNOLOGY HANDBOOK
BADGER ARMY AMMUNITION PLANT

Liquid wastes can be sprayed on the solids to increase the heating value of the feed stream, or liquids can be introduced directly into the secondary chamber burners. Maximum particle size in the waste feed is limited to a 2-inch diameter; feed rates range from 25 to 200 tons per day.

Rotary Kiln Incineration. This is a well-developed technology used to incinerate various wastes in a rotating combustion chamber (see Figure 3-1). Operating temperatures typically range from 1,600 to 2,000°F. VOCs pass into a secondary combustion chamber for additional destruction at high temperatures (2,200 to 2,600°F). Probably the most flexible technology in terms of waste feed characteristics, rotary kiln units tend to be larger and more expensive than other thermal-destruction techniques. These incinerators can handle from 50 to 150 tons of contaminated wastes per day.

Fluidized Bed Incineration. At least two types of fluidized bed processes have been developed recently for hazardous waste destruction involving the injection of liquids, sludge, or granular solids into a highly turbulent bed or granular material under high temperature conditions (i.e., 1,500 to 1,600°F). Organics are volatilized and destroyed in a secondary chamber (see Figure 3-1), and solids reduced to a fine ash residue. These units handle a maximum waste feed particle size of about 1-inch diameter; waste feed rates range from 50 to 250 tons per day.

Air pollution control equipment is generally necessary to meet applicable emissions limits for incinerators. Both the infrared and rotary kiln systems use the combination of a packed tower followed by a wet Venturi scrubber to control particulates. For a fixed facility, a wet electrostatic precipitator may be used for particulates. If operated correctly, this equipment is sufficient to achieve regulatory compliance.

The fluidized bed process can achieve emissions control by introducing a caustic component (lime is often used) into the reactor bed. Air pollution control equipment can then be limited to particulate control. Electrostatic precipitators or baghouses are appropriate.

Off-site Incineration. Off-site incineration would require the material to be excavated and transported to an existing incineration facility. Commercial facilities are currently being operated by several hazardous waste management companies.

3.1.2 Technology Assessment

Reduction of Toxicity, Mobility, and Volume. A destruction and removal efficiency greater than 99.9999 percent for hazardous organics in soils has been demonstrated for incineration. Because most contaminants are permanently destroyed, incineration significantly reduces the volume of organic contaminants. However, the mobility of heavy metals may increase after incineration. If contaminated soils contain heavy metals, post-treatment of incinerator ash may be required to reduce mobility. The volume of contaminated soil is moderately reduced through incineration.

Treatment Time. The time required to implement an incineration system can vary greatly, depending on the type used. Mobile units have an average throughput of 75 tons per day for solids, and require approximately four months for mobilization, site preparation, and construction.

Typical downtime estimates for incineration systems, required for system maintenance and inspections, are 20 to 30 percent for a system operating 24 hours a day, seven days a week. Actual downtime for the infrared system used during the Superfund Innovative Technology Evaluation (SITE) demonstration at the Peak Oil site in Brandon, Florida, exceeded these estimates.

Most off-site facilities require that contaminated material be packaged in incinerable containers prior to receipt at the facility. However, at least one facility is known to accept shipments of material in bulk. Treatment time is limited by the rate of removal of material from the site and by the operating capacity of the facility.

Potential Impact to Public Health and the Environment. Air quality impacts from incinerators can pose a potential risk to the community during remedial action if highly concentrated wastes are burned. Potential adverse effects as a result of implementing incineration include (1) releases of low levels of products from incomplete combustion during process upsets, and (2) releases of particulate matter containing heavy metals. Air monitoring and/or control of particulates and organic compounds would have to be conducted to prevent exceedance of national and local air quality standards. Incineration systems do not pose significant safety hazards when operated by trained personnel in a properly controlled facility. Incineration systems are equipped with automatic feed shut-off controls in case of process upsets.

Secondary Waste Management Requirements. Incineration systems produce three types of effluents: (1) combustion gases (e.g., nitrogen oxides and carbon dioxide),

(2) treated solids, and (3) scrubber water and particulates. Combustion gases, which are treated to remove hydrochloric acid and particulates, are released through the stack, requiring no further treatment. Treated soil exits the primary combustion chamber as a sterile solid effluent. Air pollution control devices have an effluent stream composed of water from the wet scrubbers and/or particulates. Each effluent stream must be treated separately.

If the solid effluent is not a RCRA-listed or characteristic waste, it may be disposed of without further treatment. However, decontaminated solids may contain metals at levels near the concentrations in untreated soil, and may have hazardous characteristics as defined by the TCLP test. Three options exist for treatments and/or disposal of these solids: (1) disposal in a RCRA-approved landfill, (2) fixing the metals in the treated soil by adding a solidification or stabilization agent and disposing of the solidified or stabilized material, or (3) removing the metals from the treated soil by washing or extraction methods and then treating the concentrate. Further treatment of the soil or treatment residuals may require permitting under RCRA.

Effluents from air pollution control devices include particulate catch from electrostatic precipitators, or baghouses, and scrubber water. If particulates are caught in the dry form, they may be handled in the same manner as treated soil. Some metals tend to partition from the soil to particulates. Because particulates may have a higher metals content than sterile soil, separate TCLP testing may be necessary.

Liquid effluent from the scrubber system may contain hydrochloric acid if substantial concentrations of chlorinated compounds are incinerated. This stream is usually neutralized using a solution of sodium hydroxide, which precipitates as a salt. The scrubber water blowdown stream is an aqueous solution of sodium chloride with high suspended solids. This stream will contain some metals as a result of entrapped particulates. The scrubber water stream is a low-volume stream and could easily be treated in a wastewater treatment facility.

Technical Feasibility and Reliability. Incineration is technically feasible and proven for the destruction of organic chemicals over a wide range of concentrations. However, wastes containing high concentrations of explosive compounds may require specially designed incinerators because of their explosive potential. Incineration systems originally were designed to handle the destruction of wastes with some energy content. Wastes with limited energy content may be supplemented with

auxiliary fuels to achieve necessary temperatures. The use of auxiliary fuel does not alter the effectiveness of incineration, but results in higher cost. This cost can be minimized by dewatering the soil prior to treatment, if necessary.

Fine-grained soils may require modified particulate control devices to handle high particulate loading. These modifications are well within the technology capabilities.

Incineration has been demonstrated as a reliable method of permanently reducing the toxicity of organic contaminants, including VOCs, SVOCs, polynuclear aromatic hydrocarbons (PAHs), and polychlorinated biphenyls (PCBs). Incineration is the most widely practiced and permitted method of destroying organic hazardous wastes.

Demonstrated Performance. Incineration systems have been field-demonstrated for soils, sediments, VOCs, PAHs, high-moisture-content wastestreams, and fine-grained wastestreams. Incineration technology has been used for site remediation at the Denny Farm site in McDonnell, Missouri, and the Lenz Oil site in Illinois. The U.S. Army completed incineration operations at the Cornhusker Army Ammunitions Plant near Grand Island, Nebraska, where approximately 40,000 tons of explosive-contaminated soils were processed. Incineration operations were used to treat 101,000 tons of explosive-contaminated soil at the Louisiana Army Ammunitions Plant. The USEPA SITE demonstration at the Peak Oil site in Florida also treated approximately 400 tons of oil-like material.

Availability of Technology and Related Services. Mobile units capable of treating 75 tons of soil per day are available. Several commercial vendors and remediation companies marketing incineration equipment and services also exist.

Monitoring and Maintenance Requirements. Incineration systems require sophisticated monitoring instrumentation to control the combustion process. Monitoring instrumentation provides continuous data on the following parameters:

- fuel feed rates and pressures
- waste feed rates
- temperatures of primary and secondary combustion chambers
- operating conditions of air pollution control equipment

- combustion gas concentrations (i.e., oxygen, carbon dioxide, carbon monoxide, and total hydrocarbons)
- combustion air flow rates

These data are used to optimize the combustion process and provide an indication of combustion efficiency.

Typical maintenance includes regular inspections during operation, and periodic shutdowns to perform preventive mechanical maintenance. Fans, pumps, and compressors require regular maintenance. Moving parts operating in the combustion zone are subject to degradation as a result of heat stress. The combustion chamber refractory must be replaced as part of regular maintenance. Air pollution control devices are complex and require maintenance. Maintenance costs and time requirements are generally greater for infrared incinerators as a result of wear on moving conveyor parts in the combustion chamber.

Treatability Studies. If incineration is chosen as a remedial alternative at BAAP, a trial burn is required to demonstrate the ability to achieve required standards. However, due to the demonstrated performance and effectiveness of incineration, treatability investigations are not likely to be recommended.

Capital Costs. Capital costs for on-site incineration include mobilization/ demobilization, equipment, and site preparation. For a mobile incineration unit, mobilization costs range from approximately $600,000 to $1,200,000. These costs include installation of equipment, utilities, and labor required for mobilization. Equipment costs are not available for mobile units, which are usually employed on a unit cost per ton of processed material. Off-site incineration has no direct capital costs.

Indirect capital costs include engineering, permit applications, and administrative costs. Permitting and administrative expenses and engineering services each may range between 5 and 10 percent of total remedial construction costs.

Operation and Maintenance Costs. O&M of on-site incineration facilities include costs associated with fuel, utilities, labor, equipment, supplies, monitoring, and administrative support. Operations crews include a staff of approximately 30 trained operators, and maintenance and monitoring personnel. Standard operations continue 24 hours a day, seven days a week. Typical downtime estimates range from as low

as 5 percent for a large-scale fluidized bed in continuous operation, to 30 percent for an infrared incinerator. Maintenance costs for fluidized bed and rotary kiln units are approximately 10 percent of capital costs per year.

Operation costs for on-site incineration generally range from $200 to $325 per ton excluding materials handling, and residuals transport and disposal. Off-site incineration costs range from $1,700 to $5,500 per ton excluding materials handling and transport. Costs for off-site incineration are highly dependent upon available capacity of the incineration facility.

Cost Sensitivity. Cost estimates are based on several assumptions, which could change at the time of construction. For incineration, factors that would significantly alter cost estimates include the following:

- Difficulties in materials handling would increase costs.
- Increased moisture content in the waste feed would result in higher costs; lower moisture content would reduce costs.
- Increased fuel oil costs would result in increased operating costs.
- Post-treatment and effluent disposal costs could significantly increase incineration costs.
- Final costs depend on the total volume treated and amount of time for cleanup.

Summary. The major advantages and disadvantages of the incineration process are summarized in Table 3-1.

3.1.3 Potential Site Applicability

Because of the highly efficient destruction of organic compounds by incineration, this technology is applicable to any sites at BAAP with organic contaminants in the soil. Specifically, the Propellant Burning Ground, Deterrent Burning Ground, and the Settling Ponds and Spoils Disposal Area are possible sites where incineration of contaminated soil may be applicable.

TABLE 3-1
EVALUATION CRITERIA SUMMARY: INCINERATION

REMEDIAL TECHNOLOGY HANDBOOK
BADGER ARMY AMMUNITION PLANT

Incineration technologies use high-temperature oxidation under controlled conditions to destroy organic constituents in liquid, gaseous, and solid wastestreams.

EFFECTIVENESS	IMPLEMENTABILITY	COST
Advantages	Advantages	Advantages
• Destruction and removal efficiency of 99.9999%	• Demonstrated technology	• Because it is a proven technology, costs incurred go directly into remediation and not research and development
• Effective on a wide range of organics including volatile and semivolatile organics, polychlorinated biphenyls, and polynuclear aromatic hydrocarbons	• Mobile units are available	
• Treated soils passing TCLP testing and meeting remediation goals can be backfilled	• Widely used for destroying organic hazardous wastes	
• Effective on a wide range of concentrations	• Experienced vendors are available	
• Feed rates average 75 tons/day for mobile units	• Several off-site incinerators are currently operating	
Disadvantages	Disadvantages	Disadvantages
• Mobility of metals in incinerated soil may be increased	• Trial burn is required to demonstrate ability to achieve required standards	• Incineration is expensive; \$600,000 to \$1.2 million for mobilization of mobile units; operating costs are \$200-325/ton for on-site incineration alone
	• Wisconsin air emission standards and permitting requirements must be met.	
• Ash that does not pass the TCLP test for metals requires RCRA landfilling or solidification and disposal	• Time required to receive a RCRA permit may be considerable	
• Air emission controls are necessary for particulates and organics	• Waste with limited energy content requires the addition of auxiliary fuels during treatment	• Off-site incineration costs range from \$1,900 to \$5,500/ton
• Particulates from air pollution control devices require treatment if they fail TCLP tests	• Sophisticated monitoring instrumentation is required to control the combustion process	• Costs are sensitive to moisture content
• Liquid effluent from emission controls may contain hydrochloric acid	• Excavation is required	
• Particle size is limited; sorting is required	• Waste with high moisture content may require dewatering	

Notes:

3.2 Solvent Extraction

This subsection discusses solvent extraction.

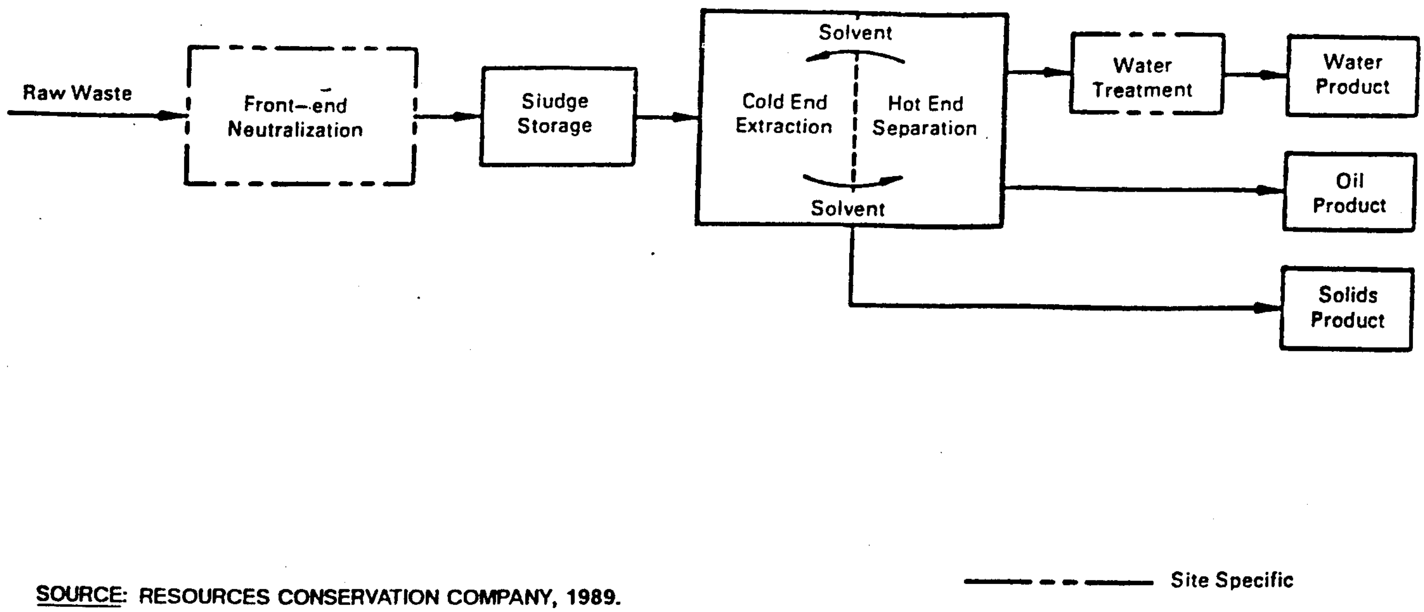
3.2.1 Description

Solvent extraction uses a chemical solvent or water to separate contaminants from soil. The process may be applied to soil contaminated with metals and/or organics. In the extraction process, solvent is first mixed with contaminated soil in a batch mixer. The soil is then allowed to settle out and the solvent/contaminant solution is decanted from the soil. The contaminant is then separated from the solvent.

Resource Conservation Company (RCC) developed the Basic Extractive Sludge Treatment (B.E.S.T), which uses triethylamine (TEA) as a solvent. During the extraction process, TEA is mixed with contaminated soil at a temperature at which TEA is simultaneously miscible with water and the contaminant (i.e., less than 30°C). The solvent extracts organics sorbed to soil particles. The soil/solvent mixture is centrifuged or filtered to remove soil from the solvent. The soil is then dried to recover any residual solvent. The TEA/contaminant/water mixture is heated, separating the aqueous and organic fractions. The top fraction, which consists of TEA and contaminant, is sent to a stripping column where TEA is recovered and the contaminant discharged. The bottom fraction, predominantly water, is sent to another stripping column to remove residual product. The TEA solvent is recycled and reused. A process diagram for B.E.S.T. is shown in Figure 3-2.

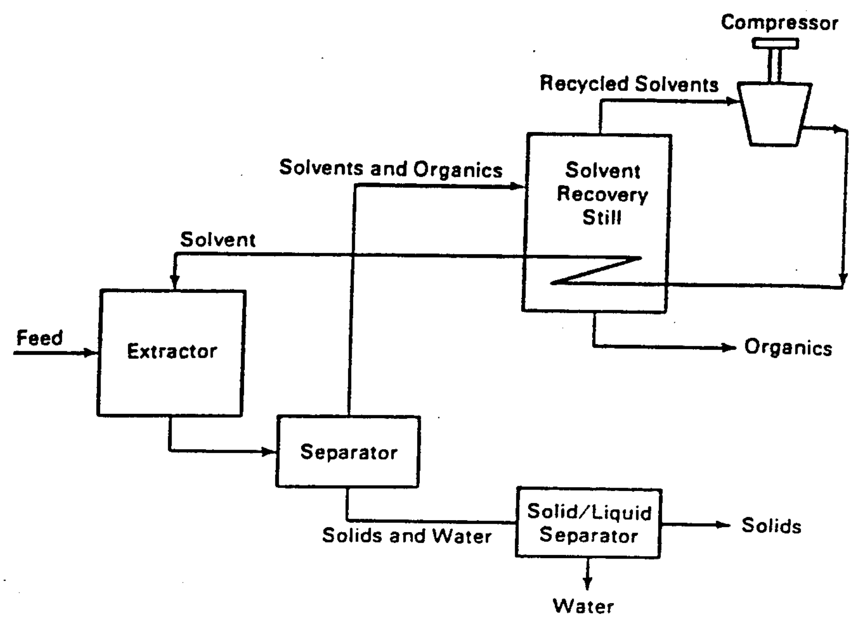
Other solvents (i.e., water and surfactants) also have been used to implement other extraction processes. C.F. Systems developed a solvent extraction process using liquid propane or carbon dioxide as the solvent. Once the contaminant is extracted from the soil it can be separated from the solvent by changing the pressure and flashing off the solvent. This process, known as liquid gas extraction, is addressed in this subsection because of its similarity to solvent extraction. The C.F. Systems process is shown in Figure 3-2.

The solvent extraction process does not destroy contaminants; it only removes them from soil. The concentrated contaminant wastestream requires further treatment before being disposed of or destroyed. Treated soils can be backfilled if they meet remediation goals.



SOURCE: RESOURCES CONSERVATION COMPANY, 1989.

CHEMICAL EXTRACTION (B.E.S.T.)



SOURCE: CF SYSTEMS CORPORATION, 1989.

LIQUID GAS EXTRACTION

FIGURE 3-2
SOLVENT EXTRACTION PROCESS
REMEDIAL TECHNOLOGY HANDBOOK
BADGER ARMY AMMUNITION PLANT

3.2.2 Technology Assessment

Reduction in Toxicity, Mobility, and Volume. Solvent extraction removes 50 to 90 percent of contaminants from soil in each extraction step. Multiple extractions may be required to achieve desired contaminant concentrations. Although the concentrated contaminant wastestream produced by the process requires further treatment, it is of considerably less volume than the original contaminated soil.

TEA is a moderately toxic compound. The B.E.S.T process uses a dryer to remove remaining water and solvent from the soil after treatment. Typically, the residual TEA remaining with the treated soil after drying is less than 200 mg/kg. Residual TEA in soil can be effectively treated by biodegradation.

Treatment Time. Initial implementation of the solvent extraction process varies with size of the unit. Transportable units with throughputs of 100 tons per day can be mobilized and set up within several months. Large dedicated units with throughputs of 200 to 500 tons per day may require a year or more for design, fabrication, installation, and start-up.

As discussed previously, throughputs for extraction units range from 100 to 500 tons per day; however, these rates are affected by soil characteristics. Soils with high percentages of fines or high levels of contamination may lower process rates. Fine soil requires longer settling times, and highly contaminated soil may require multiple passes through the unit.

Potential Impact to Public Health and the Environment. Solvent extraction may have an adverse effect on public health and the environment if toxic solvents are used in the process and are not completely removed from the soil. Steam-stripping and drying steps are used in the process to remove residual solvent from the soil. Additional treatment (e.g., biodegradation) may be necessary to reduce residual solvent in the soil to acceptable levels.

The release of contaminated process effluent and air emissions of contaminants also pose threats to public health and the environment. However, if the unit is properly designed, maintained, and operated, these emissions are controlled and the risk is not significant.

Secondary Waste Management Requirements. Effluents from the solvent process are treated soil, solvent, wastewater, and a concentrated contaminant liquid wastestream.

If the contaminant level in soil meets remediation goals and the treated soil fulfills land disposal criteria, the soil may be backfilled. The solvent is reused and does not require disposal. The wastewater and contaminant wastestream does require further treatment and possible off-site disposal.

Technical Feasibility and Reliability. Solvent extraction processes are technically feasible for removal of organics and metals from soils. The C.F. Systems and B.E.S.T processes work most effectively if contaminants are not tightly bound to soil particles and are readily soluble in the solvent used.

Soil particle size impacts the extraction process. The processes usually require that objects larger than 6 inches in diameter be removed from the soil before treatment. Although some fines will carry over with the solvent, neither the B.E.S.T. nor the C.F. Systems processes appear to be significantly impacted by the presence of fines.

The solvent extraction process is reliable; a 10 percent downtime for equipment maintenance can be expected.

Demonstrated Performance. Field experience of solvent extraction is limited. The B.E.S.T. process has been used full-scale to treat oil-sludge waste contaminated with PCBs at the General Refining Superfund Site in Savannah, Georgia. The C.F. Systems process has been used in pilot-scale tests for treating wastewater and oily sludge and has been tested at New Bedford Harbor as part of the USEPA SITE program.

Availability of Technology and Related Services. RCC has a 100-ton-per-day B.E.S.T. mobile unit and 25-cubic-yards-per-day (cy/day) truck-mounted unit. Larger scale units can be built by RCC as needed. C.F. Systems has no full-scale unit available; all units would have to be built as needed.

Monitoring and Maintenance Requirements. Treated and untreated soil, wastewater, contaminated effluent, and air emissions must be monitored during the solvent extraction process. By monitoring soils before and after treatment, efficiency of the solvent extraction process and the number of required extraction steps can be determined. Analysis of the effluent evaluates contaminants being removed and the further treatment required. Air monitoring is used to determine whether contaminants or excess solvents are being released to the atmosphere from this process.

Solvent extraction equipment requires periodic maintenance; a 10 percent downtime is required to perform this maintenance.

Treatability Studies. Prior to final design of a solvent extraction remedial system, a treatability study would need to be performed on representative samples of the material. The study will determine the amount of solvent, the number of passes, and other parameters required for operation of the solvent extraction unit.

Capital Costs. Cost estimates vary widely according to site characteristics and whether a unit is dedicated or mobile. RCC estimates capital and O&M costs of $200 to $350 per cy for a stand-alone mobile unit. Owner-operated, large, integrated industrial facilities would have lower unit costs. The estimated unit cost for a 500-cy/day B.E.S.T. unit, used to treat 450,000 cy of contaminated sediment, is approximately $100 per cy.

Assuming all site preparations have been made (e.g., concrete pad and utilities installed), mobilization/demobilization cost for a mobile unit is $20,000. Estimated mobilization/demobilization cost for a 500-cy/day unit is $800,000.

These estimates do not include the price of materials handling, treatment and/or disposal of wastewater and the contaminant wastestream, permitting, or engineering services. Permitting costs range from 5 to 10 percent of capital costs; engineering services are usually 10 percent.

Operation and Maintenance Costs. Because solvent extraction estimates are commonly given on a cost-per-unit-volume (or mass) basis, O&M costs are not readily available. The unit cost of solvent extraction is discussed in the previous subsection.

Cost Sensitivity. The costs of solvent extraction are sensitive to the following factors:

- Water Content of the Soil. More water means a greater volume to treat and, therefore, higher costs.
- Process Times. The longer the process times, the more time must be spent on-site and the higher the operation costs.

- Amount of Contaminated Effluent Produced. Effluent must be treated and disposed of; therefore, higher volumes of effluent result in increased costs.

Summary. The major advantages and disadvantages of solvent extraction are summarized in Table 3-2.

3.2.3 Potential Site Applicability

Solvent extraction can be used to treat soil contaminated with organic compounds. Application of this technology may be practical at the Propellant and Deterrent Burning Grounds.

3.3 BIODEGRADATION AND COMPOSTING

This subsection describes biodegradation and composting.

3.3.1 Description

Composting is a method of biological treatment combining a nutrient source with contaminated soil to support the growth of microorganisms. The microorganisms degrade organic contaminants by using them as a carbon source.

Composting can be designed as an on-site treatment. A compost heap is constructed by adding nutrient sources to waste material at a typical ratio of 10:1 (nutrient:waste) by volume. Nutrient sources may include sawdust, animal feed, wood chips, manure, hay, straw, sewage, and sludge. These materials can usually be obtained locally at low costs.

3.3.2 Technology Assessment

Reduction in Toxicity, Mobility, and Volume. If the contaminant is biodegradable, composting should be successful in reducing the toxicity, mobility, and volume of contaminants. Complete biodegradation will produce biomass, carbon dioxide, and water.

Treatment Time. The time required to treat the waste depends on the volume of waste and its biodegradation rate. Set-up time is minimal because composting

TABLE 3-2
EVALUATION CRITERIA SUMMARY: SOLVENT EXTRACTION

REMEDIAL TECHNOLOGY HANDBOOK
BADGER ARMY AMMUNITION PLANT

A chemical solvent or water is mixed with contaminated soil in a batch mixer. Soil settles out and the solvent/contaminant solution is decanted off. The contaminant is then separated from the solvent to produce an effluent stream of concentrated contaminant.

EFFECTIVENESS	IMPLEMENTABILITY	COST
Advantages	Advantages	Advantages
• Removes contaminants from the soil	• Mobile units are available reducing mobilization times	• Unit costs range $100-$350/ton (excluding excavation, disposal of effluent, and mobilization/ demobilization costs)
• Effective for the removal of metals and organics	• Equipment is reliable	
• Treated soils potentially backfilled	• Technology has been demonstrated at hazardous waste sites	
• 50 to 90% of a contaminant can be removed from the soil per extraction step	• Several off-site incinerations are currently operating	
• Throughputs range from 100/tons day for mobile units to 200-500 tons/day for large dedicated units		
Disadvantages	Disadvantages	Disadvantages
• Contaminants are not destroyed	• Dedicated units may take a year or more to design, fabricate, install, and start up	• The costs given above reflect the range of passes required to meet target levels
• Multiple passes may be required to reduce contaminants to desired levels	• Technology has been demonstrated predominantly on sludge; there is little experience with soils	• High percentages of water increases the volume to be treated and therefore adversely affects the cost
• Concentrated wastestream produced requires further treatment	• Limited number of units available	• Additional treatment for residual solvent in soil would adversely affect the cost
• The same solvents may not be effective in removing all the target contaminants	• Excavation is required	
• If solvents are toxic, soil may require treatment after extraction to remove residual solvent		
• Objects larger than 6 inches in diameter must be removed from soil before treatment		

facilities can be constructed rapidly at minimal costs. Composting technology has been developed by Atlantic Research Corporation (ARC) and Roy F. Weston, Inc. (Weston) for the biodegradation of NC at the Settling Ponds and Spoils Disposal Site (ARC, 1986) (Weston, 1989).

Potential Impact to Public Health and the Environment. Composting reduces the potential long-term impact on public health and the environment if contaminants are successfully biodegraded. The major routes of exposure during the treatment process are from direct contact and particulate and vapor inhalation. These exposure routes would most likely occur during excavation, construction, and maintenance of the compost pile. Engineered solutions or personal protective equipment would reduce exposure risks.

Secondary Waste Management Requirements. When treating listed or characteristic RCRA wastes, leachate and runoff water collection may be necessary. If trace metals in leachate are of concern, chemical precipitation could be used for leachate treatment. If trace organics remain in the leachate, treatment may consist of biological treatment, carbon adsorption, or oxidation.

Technical Feasibility and Reliability. Composting is a widely used technology in the petroleum industry and has recently been developed for treatment of municipal sludge. The reliability of the process (assuming the contaminant is biodegradable) depends on adequate aeration, optimum temperature, moisture and nutrient contents, and the presence of a healthy microbial population.

Demonstrated Performance. Composting bench- and pilot-scale tests using NC-contaminated soils at BAAP were conducted by ARC. Using a hay/horse feed combination as compost material in a pilot-scale test with contaminated soil, an initial NC concentration of approximately 7,000 parts per million (ppm) was degraded to below detectable levels after three weeks (ARC, 1986). A field demonstration was conducted by Weston at BAAP to compost NC-contaminated sediments by mixing manure, alfalfa, livestock feed, and wood chips with the sediments and composting in aerated static piles. With initial NC concentrations of 13,086 ppm in one of the piles, contaminant reductions of 99.9% were attained (Weston, 1989). The capability of the composting technology if used for other contaminants at BAAP is unknown.

Availability of Technology and Related Services. Composting materials (e.g., corn stalks and cow manure) are inexpensive and readily available in the local BAAP

area. Equipment needed to handle the compost are normally off-the-shelf items and easily obtained.

Monitoring and Maintenance Requirements. During the composting operation, it is important to monitor the air flow, temperature, and moisture content of the compost heap. Mixing may be required. Leachate monitoring may be required, especially if RCRA wastes are treated. Maintenance checks of the facility during operation may be needed. Air samples, to determine the composition of gases released during composting, may be required. Compost samples to monitor the biodegradation process need to be taken.

Treatability Tests. Treatability tests (bench- and pilot-scale) were conducted by ARC on NC-contaminated soil. At the conclusion of the tests, ARC recommended a field demonstration test before full-scale implementation. Weston conducted the field demonstration and determined optimal composting parameters (i.e., temperature and nutrient:waste ratios) which could be used during full-scale implementation. To implement composting on soils from other sites containing different contaminants, bench- and pilot-scale treatability tests would be required to evaluate the feasibility and effectiveness of the technology, and to determine whether the technology should be carried to detailed analysis during the FS.

Capital Costs. Capital costs would be a function of the sophistication of the composting facility. Capital costs for a relatively complex treatment system which included concrete composting pads and automated temperature control and monitoring systems would be higher than capital costs for a treatment system with a wood chip base and manually controlled process parameters. However, the complex treatment system would be more efficient and could result in reduced O&M costs.

Operation and Maintenance Costs. Incurred O&M costs may include amendments to the nutrient source, monitoring of the process parameters, and analytical and maintenance activities.

Cost Sensitivity. The following factors may affect composting costs:

- cost of compost material
- volume of contaminated soil
- O&M activities

Summary. The major advantages and disadvantages of composting are summarized in Table 3-3.

3.3.3 Potential Site Applicability

The composting technology is applicable to the Settling Ponds and Spoils Disposal Area where NC is a major component. If the technology is considered for any other site(s), bench- and pilot-scale treatability tests would be required to determine the feasibility and effectiveness of the technology.

3.4 STABILIZATION/SOLIDIFICATION

This subsection discusses stabilization/solidification.

3.4.1 Description

Stabilization/solidification (S/S) refers to the process of mixing a setting agent with a wastestream, contaminated soil, or residual to form a hard product in which contaminants are entrapped within the solidified mass. The treated end product can be a solid monolithic structure, or a dry soil-like material. Primarily, hazardous waste S/S accomplishes the following goals:

- decreases the surface area across which transfer or loss of entrapped contaminants can occur

- reduces the solubility and mobility of the entrapped contaminants

Related technologies, such as chemical stabilization or fixation, generally refer to the addition of materials that primarily act to maintain wastes in the least toxic or mobile form, and may or may not cause a change in physical characteristics of the waste.

S/S can be performed using the following two methods: (1) mixing with the setting agent in mobile or semipermanent batch mixers, or; (2) in situ using special drilling/mixing equipment. S/S has been used for inorganic and radioactive wastes and substantial documentation of the effectiveness of this process exists for these waste types. Organic wastes, however, are less amenable to conventional solidification treatment technology. At some concentrations, organic contaminants may interfere with setting reactions, while other organics are not adequately bound

TABLE 3-3
EVALUATION CRITERIA SUMMARY: COMPOSTING

REMEDIAL TECHNOLOGY HANDBOOK
BADGER ARMY AMMUNITION PLANT

Composting combines a nutrient source with contaminated soil to support the growth of microorganisms that will degrade the organic contaminants.

EFFECTIVENESS	IMPLEMENTABILITY	COST
<u>Advantages</u>	<u>Advantages</u>	<u>Advantages</u>
• Reduces mobility, toxicity, and volume of contaminants on-site	• Can be performed on-site	• Compost materials normally obtained at low cost
• Complete biodegradation will produce biomass, carbon dioxide, and water	• Nutrient sources readily available	• Field demonstration test with NC-contaminated sediment has been completed
• Composting is effective for treatment of NC-contaminated soils	• Composting equipment is normally off the shelf	
	• Composting has been demonstrated during bench-scale, pilot-scale, and field demonstration tests using NC-contaminated sediment from the Settling Ponds and Spoils Disposal Area at BAAP	
<u>Disadvantages</u>	<u>Disadvantages</u>	<u>Disadvantages</u>
• Leachate may need treatment	• Excavation, hauling, and mixing are required	• Treatability tests are necessary for contaminants other than NC
• Close monitoring required to ensure effectiveness	• Treatment system for leachate might be needed	
• Effectiveness of composting for other contaminants at BAAP is unknown		

Notes:

BAAP - Badger Army Ammunition Plant
NC - nitrocellulose

within the solidified waste structure and are susceptible to long-term leaching. However, S/S has recently been demonstrated during bench- and pilot-scale testing to be a potentially viable treatment technology for some organic wastes.

Of the available S/S processes being marketed, most can be classified as either silicate-based or Portland cement-based. Typical additives or setting agents include Portland cement, fly ash, kiln dust, lime, silicates, and gypsum. Other processes, such as thermoplastic techniques and polymeric processes, have specialized applications and generally are not applicable to hazardous waste site remediation.

Cement-based S/S involves mixing the wastestream with Portland cement using conventional mixing equipment. The cement reacts with water to form a rigid matrix, and the waste becomes incorporated within the hardened mass.

Silicate-based S/S involves addition of a silicate source along with a setting agent. Silicates often are added in the form of fly ash, blast furnace slag, cement kiln dust, or soluble silicates such as potassium or sodium silicate. The setting agent is typically Portland cement or lime, although other suitable materials are available. Proprietary additives have been developed by several vendors to immobilize various organic and inorganic contaminants.

3.4.2 Technology Assessment

Reduction in Toxicity, Mobility, and Volume. The cement S/S process reduces the mobility of contaminants. The process is particularly useful for reducing the mobility of metals because, at the elevated pH of the cement mixture, most metals are immobilized as insoluble hydroxides or carbonates.

The effect of organic constituents on the short- and long-term integrity of the solidified material is difficult to quantify. Effects of ethylene glycol, p-chlorophenol, and p-bromophenol on physical properties of Type I Portland cement have been researched (Sheffield et al., 1987). At high organic:cement weight ratios (i.e., 1:5 to 1:23), organics were found to inhibit the setting of Portland cement and decrease its compressive strength. Recent research on prepared samples contaminated with both inorganic and organic constituents indicate S/S did not appear to reduce the leaching of organic chemicals, as measured by the TCLP test (Weitzmann et al., 1988). While VOC and SVOC concentrations decreased during the solidification process, the decrease was attributed to volatilization during processing and curing. The research

did conclude it should be possible to immobilize organic contaminants with a proper choice of solidification reagents.

The S/S process significantly reduces the mobility of some contaminants; however, it does not reduce toxicity. S/S may also result in a 20 percent or more increase in the volume of material.

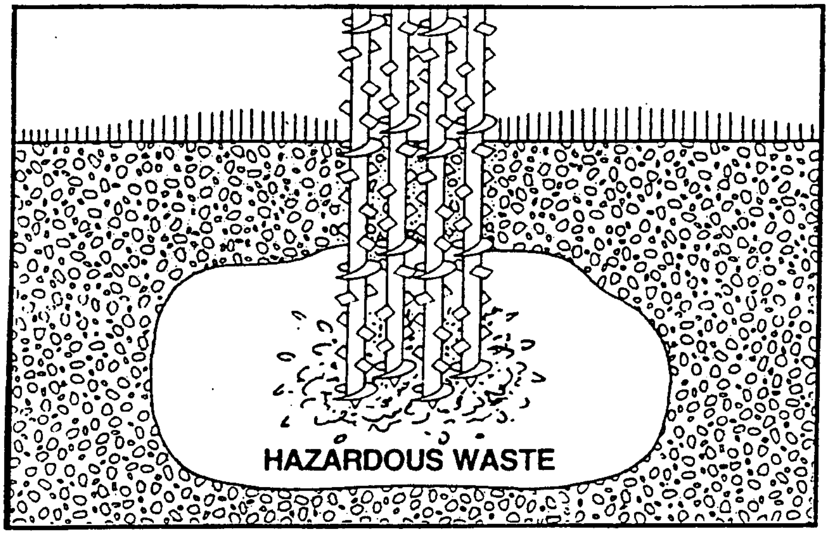
Treatment Time. The time required to set up a full-scale S/S operation is estimated at six to eight weeks. Assuming a batch-mixing process is used, the throughput of the S/S process is typically 40 cy per hour.

Potential Impact to Public Health and the Environment. S/S reduces the potential long-term impact to public health and the environment due to contaminant exposure if immobilization is successfully achieved. The major routes of exposure during the treatment process are from direct contact, and particulate and vapor inhalation. Direct contact exposure can be minimized by restricting access to the site and the use of protective equipment by workers. Continuous air quality monitoring may be required to determine whether significant risks from vapor inhalation exist.

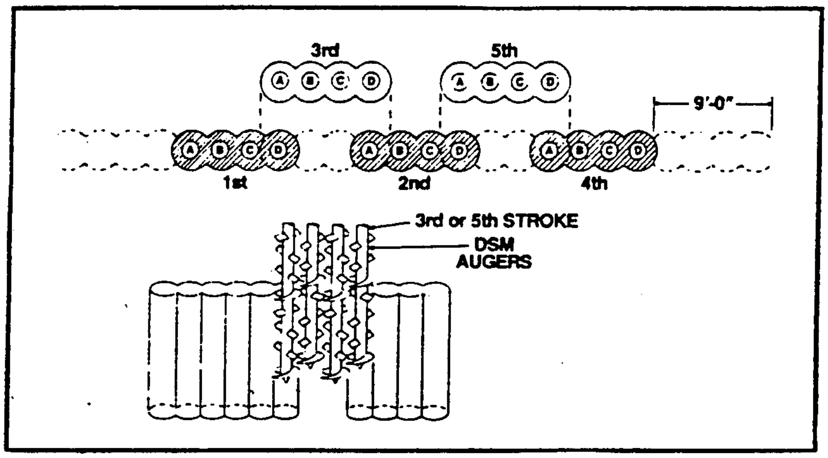
Secondary Waste Management Requirements. The only effluent from the S/S process is the treated product. Post-treatment requirements for the solidified material, if any, depend on results of bench-scale tests and institutional constraints. If S/S does not sufficiently reduce long-term leaching of contaminants, the solidification end product must receive further treatment to comply with RCRA Subchapter I, Part 268 Land Disposal Restrictions (i.e., Land Ban).

Technical Feasibility and Reliability. S/S is technically feasible for immobilization of contaminants in soil, sludge, sediments, some liquids, and incinerator ash. The S/S process is particularly applicable to sludge and soil with high levels of metals and other inorganics. Some organics can also be immobilized; however, bench-scale testing is required to demonstrate the applicability of solidification to organic wastes on a case-by-case basis. Immobilization of organics may involve addition of proprietary reagents available only through certain vendors. The application of S/S as a treatment of liquid wastes is an uncommon occurrence and requires evaluation as a special case.

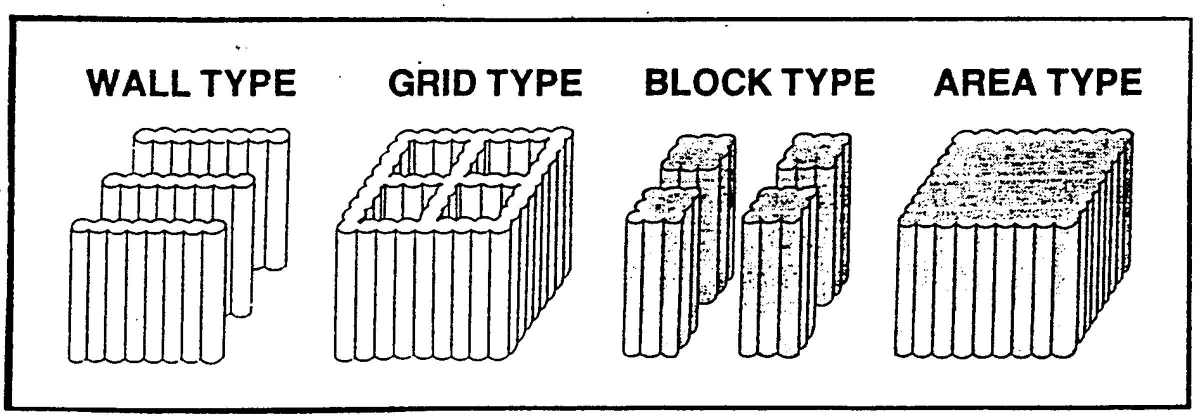
S/S may be done in situ (Figure 3-3) or with excavated soil treated in a batch process. In situ S/S requires specialized equipment and is not as reliable as batch mixing because it is difficult to control reagent/waste ratios while developing a



AUGERS LOOSEN SOIL WHICH IS THEN MIXED, IN PLACE, WITH A SOLIDIFICATION AGENT.



COLUMNS ARE OVERLAPPED TO CREATE A CONTINUOUS WALL OR BLOCK.



DIFFERENT PATTERNS CAN BE USED DEPENDING ON SITE REQUIREMENTS.

SOURCE: GEO-CON

FIGURE 3-3
IN-SITU STABILIZATION
USING DEEP SOIL MIXING EQUIPMENT
REMEDIAL TECHNOLOGY HANDBOOK
BADGER ARMY AMMUNITION PLANT

uniform mixture. When S/S is used to treat large volumes of excavated waste, sufficient space must be available for mixing and curing operations. Space requirements can be in the range of several acres. Large rocks and debris must be screened from the wastestream to prevent damage to mixers. Conventional mixing equipment used in the process is proven and reliable; downtime is minimal.

Demonstrated Performance. S/S has been well-demonstrated in the field. However, because the process is site-dependent, treatability tests are still necessary to demonstrate the effectiveness of solidification on site-specific contaminants and to select the most effective process.

Availability of Technology and Related Services. The equipment and solidification agents required for the process are readily available. There are many vendors of solidification products and services, some of which market proprietary reagents for particular wastestreams.

Monitoring and Maintenance Requirements. Process monitoring focuses primarily on metering the materials used in the process. Periodic quality control sampling of both the influent stream and treated end product are needed to evaluate whether the proper mixture is being used and the contaminants are being immobilized. Air quality monitoring is also required to determine whether national or local standards are being exceeded. After closure, monitoring of groundwater may be necessary to detect the leaching of contaminants from the solidified material. Equipment maintenance is limited to periodic servicing of mixing equipment.

Treatability Tests. Treatability tests to determine the proper mix ratios and curing times are required if the S/S process is selected as a remedial alternative. In some cases, more detailed treatability tests prior to selection as an alternative would be required to determine whether the technology is effective at treating a specific waste (i.e., organic-containing wastes).

Capital Costs. Most cost estimates for S/S are expressed in unit price ranges, which cover total costs of the solidification process including equipment, material, labor, maintenance, overhead, and profit. Many vendors provide their own specially designed equipment as part of on-site services.

Cost estimates of S/S range from $40 to $80 per cy for a sludge (or sediment) and from $60 to $120 per cy for soils. In situ methods can be less expensive than batch-mixing processes. Costs for batch mixing do not include site preparation, excavation

of contaminated material, engineering, administrative, or legal costs. Disposal is assumed to be on-site for all estimates.

Operation and Maintenance Costs. O&M costs for S/S are included in the unit costs presented in the capital cost section. However, post-closure monitoring costs to detect leaching of contaminants from solidified material is not included and may range from $5,000 to $50,000 per year, depending on sampling frequency (i.e., quarterly, semiannually, or annually) and sampling parameters.

Cost Sensitivity. The cost of S/S depends on the physical and chemical characteristics of the waste. Existing contaminants and their concentrations determine the type and amount of reagent required. Bench-scale tests are required to determine the most effective reagent and process combinations and to accurately estimate costs. If the end product of the S/S process cannot be disposed of on-site, additional costs will be incurred for off-site disposal.

Summary. The major advantages and disadvantages of the S/S technology are summarized in Table 3-4.

3.4.3 Potential Site Applicability

The S/S technology is potentially applicable to treat inorganics at the following sites: Propellant Burning Ground, Deterrent Burning Ground, and Rocket Paste Area and Nitroglycerine Pond.

3.5 CONTAINMENT

This subsection addresses containment technologies.

3.5.1 Description

Containment on- or off-site disposal technologies provide little or no treatment, but protect public health and the environment by reducing contact with contaminants. Containment technologies attempt to reduce potential routes of exposure through isolation. Containment actions typically consist of covering contaminated soil, shipping material off-site to a RCRA landfill, or constructing an approved on-site disposal area.

TABLE 3-4
EVALUATION CRITERIA SUMMARY: STABILIZATION/SOLIDIFICATION

REMEDIAL TECHNOLOGY HANDBOOK
BADGER ARMY AMMUNITION PLANT

A setting agent is mixed with the wastestream to form a hard product. Contaminants are entrapped by the solidified mass. The most common solidification agents are Portland cement-based or silicate-based.

EFFECTIVENESS	IMPLEMENTABILITY	COST
Advantages	Advantages	Advantages
• Silicate process reduces the mobility of inorganics	• May be done in-situ or by batch mixing	• Costs for solidification (excluding excavation) are \$60-\$120/yd^3
• Process using only Portland cement reduces the mobility of inorganics and some organics	• Simple technology	
• Elevated pH of cement mixture is particularly effective for immobilizing metals	• Well-demonstrated	
• Proprietary additives are used to treat a wide range of inorganics and organics	• Several vendors offer additives and/or services	
	• Mobilization requires 6 to 8 weeks	
Disadvantages	Disadvantages	Disadvantages
• High levels of organics may interfere with the setting process of Portland cement	• Large areas may be required for batch-mixing processes	• If landfilling or further treatment is required, cost will increase significantly
• Toxicity of contaminants is not reduced	• Reagent/waste ratios are difficult to control and monitor during the in-situ process	
• Increases volume of waste by at least 20%	• Excavation is required for the batch method	
• If end product does not prevent long-term leaching or remobilization of contaminants, landfilling or further treatment is required		
• Large debris must be screened out prior to batch processes to prevent damage to equipment		

The on-site disposal area could be constructed to accept contaminated or treated soil. An on-site RCRA landfill constructed to secure contaminants would require a double-lined cell with a leachate collection system. The landfill must comply with RCRA Subchapter I, Part 268 Land Disposal Restrictions (i.e., Land Ban).

Off-site disposal requires that excavated soil or sediment be transported by truck to one or more available landfill facilities. Appropriate testing of contaminated material is required by landfill operators before receiving the waste. Several landfills that handle hazardous waste and meet RCRA standards are available. Chemical Waste Management is an example of a company that operates several landfills.

In-place containment of contaminated soils normally consists of some type of cap. Capping an area involves placing a low-permeability material (e.g., clay, asphalt, or synthetic membrane) over the area of concern to reduce direct contact exposure and precipitation infiltration. The cap would, therefore, reduce dermal contact risks and leachate production. Capping is normally performed when extensive subsurface contamination precludes excavation.

3.5.2 Technology Assessment

Reduction in Toxicity, Mobility, and Volume. Containment technology does not treat contaminants. The toxicity, potential mobility, and volume of contaminants remain the same; however, they may be in a more stable, contained environment with lower exposure potential.

Treatment Time. The time required for implementing off-site disposal depends on testing requirements, state regulations, and permitting requirements. On-site disposal implementation also depends on the type of disposal area needed, and regulations and permitting requirements. When capping an area, the size and type of cap will influence the time required for implementation.

Potential Impact to Public Health and the Environment. Containment reduces dermal contact risks. A properly constructed on-site landfill would minimize the risks associated with migration of contaminants through the use of double liners and leachate collection systems required by law for a RCRA landfill.

Off-site landfilling may pose a risk to public health and the environment if contaminated material is spilled during transport. This risk is minimized through the use of properly maintained trucks and experienced hazardous waste hauling firms.

Secondary Waste Management Requirements. There are no secondary wastes produced by containing contaminated soil either on- or off-site.

Technical Feasibility and Reliability. Containment or on-site disposal is technically feasible. However, the design life of a cap is uncertain, due to the lack of historical data on the expected life of synthetic and natural liners. Reliability of the containment system is related directly to the amount of rainfall that may infiltrate through the natural or synthetic materials, and the resulting rate of waste migration in groundwater. These infiltration amounts can be predicted before construction using available empirical models. Installation of monitoring wells is necessary to track migration of the waste and determine the effectiveness of the cap or disposal area.

Demonstrated Performance. Containment of contaminated soils is a common method of remediation; however, treatment of the contaminant may be preferred over containment. Land Ban restrictions have also limited the availability of landfills for certain waste types.

Availability of Technology and Related Services. Contractors capable of constructing a cap or landfill are readily available. Many off-site landfills are available; however, implementation of Land Ban restrictions limit the types of waste that can be disposed of in landfills.

Monitoring and Maintenance. Because the contaminated material would remain in place, an environmental monitoring program would be required.

Maintenance of a cap includes inspection for signs of erosion, settlement, and subsidence. Periodic mowing of the vegetative layer is necessary to prevent invasion by deep-rooted vegetation and burrowing animals.

Any soil to be disposed of off-site must be sampled to determine whether it meets requirements of the disposal facility.

Treatability Tests. Treatability tests for containment technology are not required.

Capital Costs. The costs to construct an on-site landfill depends on the size of the facility, the complexity of the liner and leachate collection system, number and type of monitoring wells, and site-specific engineering factors.

Operation and Maintenance Costs. If an on-site RCRA landfill is constructed, maintenance costs of the leachate collection system will be incurred. During operation, run-on of rainwater should be prevented, disposed waste materials compacted, and stormwater and leachate controls inspected and repaired if necessary.

Costs associated with off-site landfilling are capital costs only.

Cost Sensitivity. The following factors affect containment costs:

- area of contamination to be covered - an increase in the expected area of contamination may significantly impact costs
- size and necessity of a RCRA-approved on-site landfill
- contaminant type - if contaminants prohibited from land disposal are found, more costly disposal methods may be required
- distance from site to landfill - transportation is usually billed on a per-mile basis; shipping to a more distant landfill results in higher transportation costs
- changing state or federal regulations

Summary. The major advantages and disadvantages of the containment technology are summarized in Table 3-5.

3.5.3 Potential Site Applicability

Containment technology may be applicable to the following sites: Propellant Burning Ground, Deterrent Burning Ground, Settling Ponds and Spoils Disposal Area, Rocket Paste Area, and Nitroglycerine Pond.

3.6 ANAEROBIC THERMAL PROCESS

This subsection describes the anaerobic thermal process (ATP).

Table 3-5
Evaluation Criteria Summary: Containment

Remedial Technology Handbook
Badger Army Ammunition Plant

Containment actions at BAAP may consist of covering contaminated soil, shipping material off-site to an RCRA landfill, or constructing an approved on-site disposal area.

Effectiveness	Implementability	Cost
Advantages	Advantages	Advantages
• RCRA on-site (if constructed) landfills have double liners and leachate collection systems to help prevent contaminant migration	• Commonly used method of remediation	• Funds spent for off-site landfilling go directly toward site remediation
• There are no secondary wastes produced	• Caps can be easily constructed	
• Contaminants may be relocated to a more stable, contained, lower exposure potential environment		
• Off-site landfilling reduces the volume of contaminants on-site		
Disadvantages	Disadvantages	Disadvantages
• Contaminants are not treated, soil either remains in place (cap) or is transferred from one site to another (landfill)	• Excavation and hauling may be required	• Off-site landfilling costs are expensive
• Contaminants may migrate from under cap or from the landfill	• Long-term maintenance	• Off-site disposal costs susceptible to rising landfill costs
• Uncertain design life	• Several waste types may be restricted from landfilling because of Land Ban restrictions	• Off-site disposal costs depend on distance to landfill
• In off-site disposal, contaminated soil is transported over public roads and may be subject to spills		
• Off-site disposal may be delayed if landfill is temporarily out of compliance		
• Contaminated soil may be rejected after analysis by the receiving landfill		

Notes:

BAAP - Badger Army Ammunition Plant
RCRA - Resource Conservation and Recovery Act

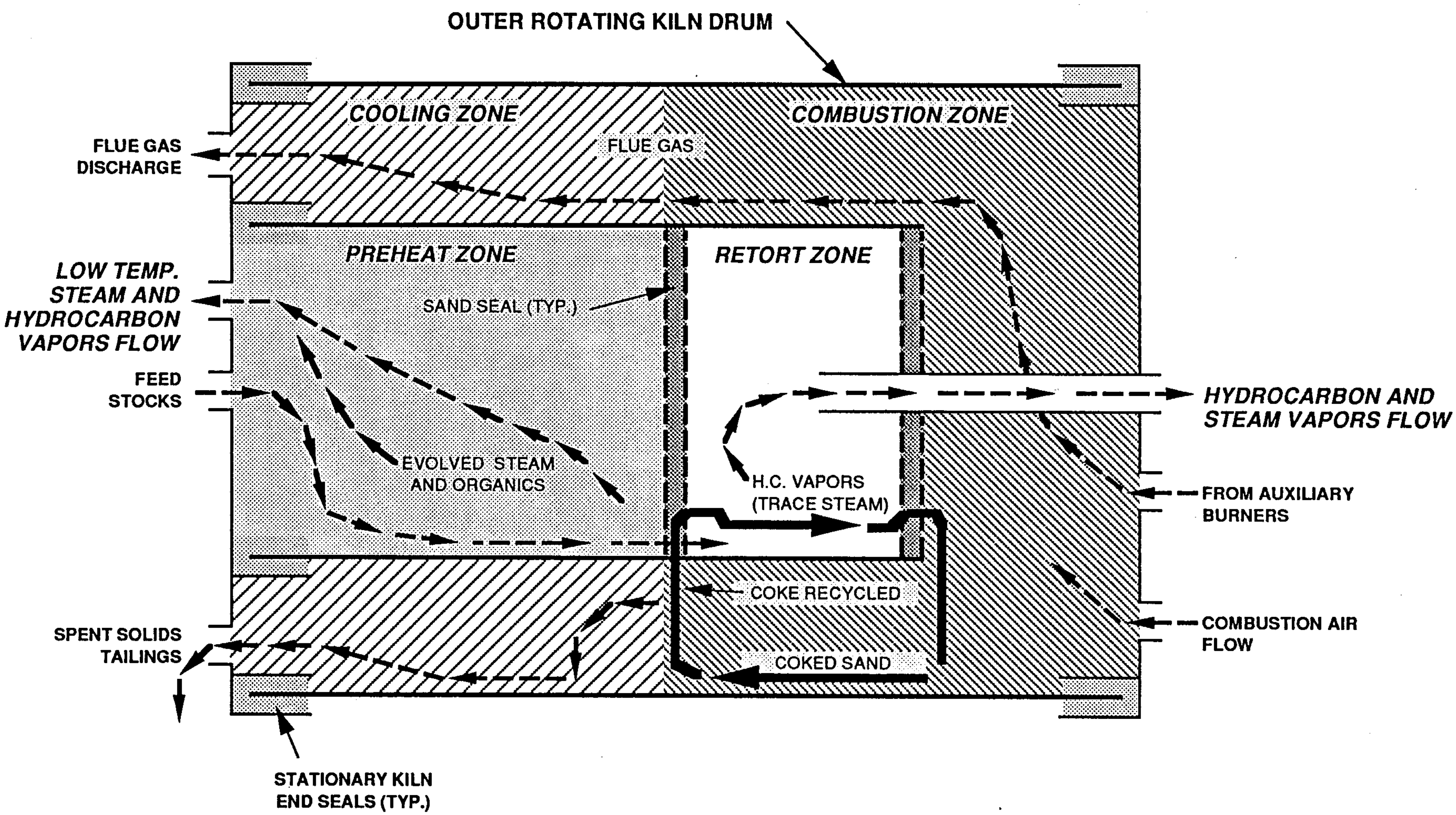
3.6.1 Description

The ATP was originally developed to produce oil from Athabasca tar sands in the Province of Alberta, Canada. The process is designed for maximum oil recovery (minimum oil destruction) and maximum heat transfer efficiency. These features are the ones which make the process effective for obtaining low residual levels of contamination in soil without discharging significant quantities of treatment byproducts or contaminants into the air.

The design of the processor is illustrated schematically in Figure 3-4. The system is a rotating kiln with an inner shell and four internal zones which perform the functions of heating, retorting, combustion, and cooling (Montgomery, A.H., 1990). The waste material is fed into the processor using a conveyor belt. The waste is heated indirectly from the outer shell by the hot processed material exiting the processor. Preheating to about 500°F is necessary to remove water from the waste prior to entering the retort zone.

The heat for retorting is provided in this zone by direct contact and mixing with hot soil recycled from the combustion zone. This recycle raises the temperature of the waste almost instantaneously from about 500 to 1,050°F, resulting in the thermal stripping of semi-volatile and volatile contaminants from the soil in the retort zone. The intimate mixing of hot soil and waste material is primarily responsible for the high degree of thermal stripping achieved in the processor. The retort zone is purposely maintained at a low oxygen partial pressure to prevent burning or oxidation of contaminants. If the waste contains oil, some coking occurs in the retort zone, and the soil particles become coated with carbon. The soil is then discharged into the combustion zone where air is injected to burn the deposited carbon. Burning the carbon raises the temperature of the soil from about 1,050 to 1,250°F. A large part of the hot soil is recycled back into the retort zone to provide the heat source for thermal stripping. The remaining soil is discharged through the cooling zone where it gives up its heat to incoming waste by indirect heat transfer.

Steam and light oil products are condensed from the preheat zone gas stream using conventional heat exchangers. The condensed water product is treated using conventional water treatment technology prior to discharge. Non-condensable contaminants emitted from the preheat zone are recycled to the burners for combustion.



SOURCE: MONTGOMERY, A.H., NOVEMBER 1990.

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FIGURE 3-4
ANAEROBIC THERMAL PROCESS
REMEDIAL TECHNOLOGY HANDBOOK
BADGER ARMY AMMUNITION PLAN

ABB Environmental Services, Inc.

The vapor emitted from the retort zone is condensed in a vapor train system designed for site-specific contaminants. Depending upon the application, the system produces a recyclable or concentrated contaminant product. Non-condensable gases from this train are also recycled to the burners.

3.6.2 Technology Assessment

Reduction in Toxicity, Mobility, and Volume. Pilot-test data from recycling of oily refinery wastes and treatment of PCB-contaminated soils show that the ATP is capable of reducing organic contamination in solids to non-detectable levels. Data from a "proof-of-process" full-scale demonstration at the Wide Beach Superfund site in New York show that the ATP, supplemented by adding dechlorination chemicals to the feed material, resulted in reductions of PCBs in soil by greater than 99% (Montgomery, A.H., 1990).

In the absence of dechlorination chemicals, the ATP will not destroy contaminants but will concentrate them into a wastestream. Although the wastestream requires further treatment, it is of considerably less volume than the original volume of contaminated soil.

Treatment Time. The only commercial ATP currently available is a transportable unit rated at 10 tons per hour. Total residence time is 30 to 45 minutes. A high percentage of fines in the waste negatively impacts processing rates. Coarse sand would have to be added to the waste to provide material for hot sand recycle into the retort zone, resulting in reduced waste processing rates. Moisture content also has a significant negative effect on ATP processing rates. Water must be totally removed in the preheat zone to avoid pressure fluctuations in the retort zone, resulting in longer residence times and reduced waste processing rates.

Potential Impact to Public Health and the Environment. The only air emission is the combustion flue gases. The air pollution control system removes particulates, acid gases, and residual toxic gases. Since the ATP operates at low temperatures under anaerobic conditions, the possibility of emitting nitrogen compounds or chlorinated decomposition products (furans and dioxins) is minimal. As the ATP does not typically use chemicals during processing, residuals do not convey treatment byproducts into the environment.

Secondary Waste Management Requirements. Emissions from the ATP are treated soil, wastewater, concentrated contaminants, and flue gas. If the contaminant level

in soil has been reduced sufficiently and the treated soil fulfills land disposal criteria, the soil may be backfilled. The wastewater and contaminant wastestream require further treatment and/or off-site disposal.

Technical Feasibility and Reliability. The ATP is technically feasible for removal of organics from soil. The ATP works most effectively if the waste has a low percentage of fines and low water content. The upper size limit on feed material is 2 inches, determined by the size of material which can pass through the seals between chambers.

The ATP is reliable; a 20 to 30 percent downtime for equipment maintenance can be expected.

Demonstrated Performance. Commercial hazardous waste field experience is limited to the Wide Beach Superfund site. The ATP processed over 42,000 tons of PCB-contaminated soil at throughput rates of about 6 to 10 tons per hour.

Extensive pilot-scale testing has been conducted. A fixed-base 5 ton per hour ATP has processed over 24,000 tons of various oily feed materials.

Availability of Technology and Related Services. Soiltech, Inc., a subsidiary of Canonie Environmental Services Corp., operates the full-scale ATP which was used at the Wide Beach Superfund site. No other vendors currently offer ATP technology for site remediation. Soiltech also offers design and construction services for ATP applications.

Monitoring and Maintenance Requirements. Treated and untreated soil, wastewater, concentrated contaminants, and air emissions must be monitored during ATP processing. Monitoring soils before treatment will determine the need for addition of coarse sand into the waste or dewatering of the waste. Monitoring of treated soil will determine the need for longer residence times. Air monitoring is required to ensure compliance with limits set by operating permits.

Treatability Studies. Treatability studies on representative samples of soil from BAAP would be necessary to determine the effectiveness of ATP on the waste types present there. The technology has not been tested on explosive-contaminated soil, which is one of the primary soil contaminants at BAAP. The study would determine pre-treatment requirements (if any), residence time, and other parameters required for operation of the ATP.

Capital Costs. Capital costs for ATP processing, including mobilization/demobilization, are typically included in a unit cost per ton of material. At sites with greater than 50,000 cubic yards of contaminated soil, mobilization/demobilization adds only $2 to $3 to the unit cost (Crincoli, P., 1991). At sites with less than 50,000 cubic yards, mobilization/demobilization costs represent a larger percentage of the unit cost. Depending upon the application, ATP becomes cost-effective at sites with greater than 10,000-15,000 cubic yards of waste.

Indirect capital costs include engineering, permit applications, and administrative costs. Permitting and administrative expenses and engineering services each may range between 5 to 10 percent of capital costs.

Operation and Maintenance Costs. O&M of the ATP include costs associated with fuel, utilities, labor, equipment, supplies, monitoring, and administrative support. O&M costs are included in the unit cost with mobilization/demobilization. Unit costs generally range from $150 to $200 per ton, depending upon the volume of waste to be processed (Crincoli, P., 1991). Unit cost excludes costs for excavation, materials handling, and concentrated contaminant transport and disposal.

Cost Sensitivity. The costs of the ATP are sensitive to the following factors:

- Fines Content of the Soil. A high percentage of fines in the soil could result in a lower rate of heat transfer into the retort zone. Coarse sand would be added to increase heat transfer rates, resulting in lower waste processing rates and higher costs.

- Water Content of the Soil. Water must be totally removed in the preheat zone prior to the waste entering the retort zone. Higher water content means longer residence times, lower waste processing rates, and higher costs.

- Volume of Contaminated Effluent Produced. Wastewater and the contaminant wastestream must be treated and/or disposed; therefore, higher volumes of secondary waste result in increased costs.

Summary. The major advantages and disadvantages of the ATP are summarized in Table 3-6.

TABLE 3-6
EVALUATION CRITERIA SUMMARY: ANAEROBIC THERMAL PROCESS

REMEDIAL TECHNOLOGY HANDBOOK
BADGER ARMY AMMUNITION PLANT

Contaminated soil or sludge is fed into a rotating kiln with an inner shell and four internal zones which perform the functions of heating, retorting, combustion, and cooling. Moisture is removed in a preheat zone, contaminants are stripped from solids in the anaerobic retort zone, hydrocarbons coked onto particles are burned in the combustion zone, and treated solids give up heat to incoming waste in the cooling zone. Contaminants are condensed for treatment or disposal.

EFFECTIVENESS	IMPLEMENTABILITY	COST
Advantages	Advantages	Advantages
• Removes contaminants from the soil	• Technology has demonstrated attainment of cleanup levels at hazardous waste sites contaminated with PCBs	• Unit costs range $150-$200/ton (excluding excavation, materials handling, and disposal of effluent)
• Effective for the removal of volatile and semivolatile organics	• Particularly suited for soils contaminated with hydrocarbons	• Mobilization/Demobilization costs included in unit cost
• Treated soils passing TCLP testing can be backfilled	• Transportable unit is available	
• Minimal air emissions of toxic residuals		
Disadvantages	Disadvantages	Disadvantages
• Contaminants are not destroyed (unless dechlorination chemicals are added)	• Only one full-scale unit is available	• Costs are sensitive to fines and moisture content
• Concentrated wastestream produced requires further treatment	• Waste with limited energy content requires the addition of auxiliary fuels during treatment	• Cost-effective at sites with greater than 10,000-15,000 yd^3 of waste
• High percentage of fines reduces processing rates	• Excavation is required	
• High moisture content reduces processing rates	• Waste with high moisture content may require dewatering	
• Objects larger than 2 inches in diameter must be removed from soil before treatment		

3.6.3 Potential Site Applicability

The ATP can be used to treat soil contaminated with organic compounds. Application of this technology may be practical at the Propellant Burning Ground, Deterrent Burning Ground, and the Settling Ponds and Spoils Disposal Area.

3.7 In Situ Vacuum Extraction

This subsection discusses in situ vacuum extraction (SVE).

3.7.1 Description

The SVE process is a technique for the removal of contaminants from the unsaturated (i.e., vadose) soil zone. Air is injected or flows into the subsurface at locations around a spill site, and the vapor-laden air is withdrawn under vacuum from extraction wells. The process is most effective for contaminants that have dimensionless Henry's Law constant values greater than 0.01 (i.e., VOCs).

Extraction systems may be vertical (wells) or horizontal (screens installed in trenches or horizontal borings). Vacuum extraction wells are designed with a vacuum-tight seal near the surface and an extraction zone (screen) corresponding to the profile of subsurface contamination. Usually, several wells are installed at a site, especially if soil strata are highly variable in terms of permeability. Horizontal systems are particularly applicable in areas where groundwater and contamination is very shallow (i.e., less than 10 feet) and removal of groundwater is to be minimized. Construction of horizontal systems in near-surface soil would require excavating trenches across the area of contamination, placing screens and surrounding sandpack material in the trenches, and topping-off the trench with an impermeable material to prevent air from short circuiting the system.

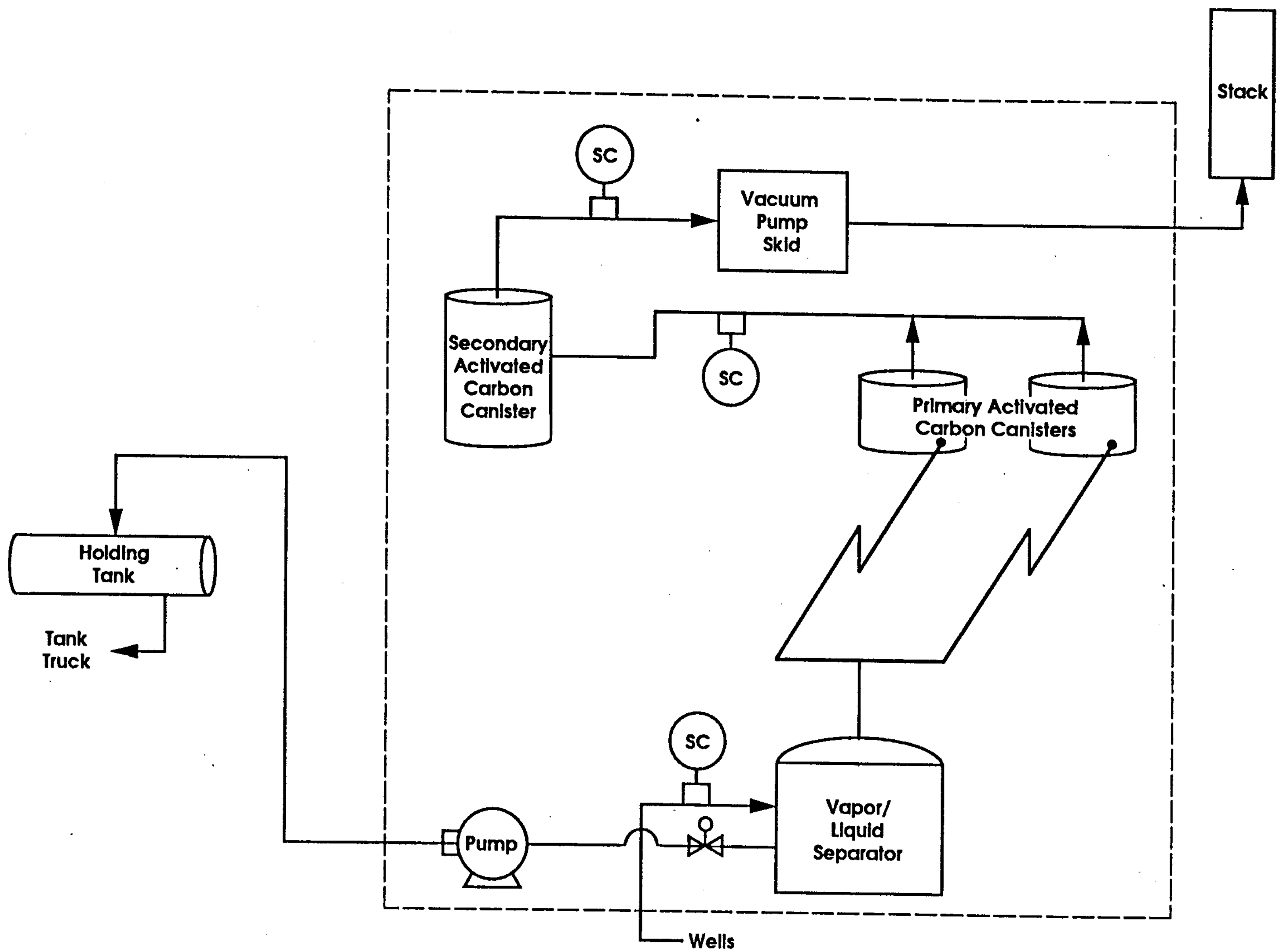
A vacuum pump or blower induces air flow through the soil, stripping and volatilizing the VOCs from the soil matrix into the air stream. Liquid water is generally extracted along with the contamination. Vacuum is applied to the vacuum extraction well via a manifold system. The vacuum at the wellhead is directly related to the radius of influence of the well and the cleanup rate that can be achieved; the higher the vacuum, the faster the cleanup. Subsurface air and vapors migrate toward the vacuum extraction well in response to the negative pressure gradient around the well.

The two-phase flow of contaminated air and water flows to a vapor/liquid separator where contaminated water is removed. Contaminated water can usually be disposed of by treating with carbon adsorption or an air stripper and discharging on site. Alternatively, contaminated water can be transported off site for disposal at a wastewater treatment facility. Treatment of vapors produced by the process are typically handled by one of three methods: dispersion, carbon adsorption, or thermal destruction. Dispersion of vapor may be an unacceptable method, depending upon the concentration of vapor in the atmosphere and applicable air standards. Typically, the vapors are treated by carbon adsorption. The contaminated air stream flows through activated carbon canisters arranged in parallel. Primary, or main, adsorbing canisters are followed by secondary, or backup, adsorbers to ensure that no contamination reaches the atmosphere. Figure 3-5 shows a representative layout of wells and equipment.

3.7.2 Technology Assessment

Reduction in Toxicity, Mobility, and Volume. Pilot-test and full-scale remediation data from Superfund, industrial, and petroleum sites across the United States show that SVE is capable of reducing VOC contamination in subsurface soils to site-specific cleanup goals (USEPA, 1989). In some cases, the process attained reductions of VOCs in soil by greater than 99%. The process also reduces the mobility of contaminants by containing the contaminants within the radius of influence of each extraction well and limiting their migration into the saturated zone. Although the concentrated contaminant wastestream produced by the process requires further treatment, it is of considerably less volume than the original contaminated soil.

Treatment Time. Treatment time is highly dependent on soil properties and contaminant chemical properties. The soil property that has the greatest influence on treatment time is the percentage of air-filled porosity (USEPA, 1989). Air-filled porosity is largely determined by soil moisture content. High soil moisture content results in a low percentage of air-filled porosity and additional treatment time is required to dewater the soil by vacuum extraction or some other means. The contaminant chemical properties that have the greatest influence on treatment time are vapor pressure and water solubility. Contaminants with a vapor pressure below 100 millimeters of HG at 25°C and high water solubility would require additional time to remediate.



Source: USEPA, Doc. No. 540/A5-89/003, July 1989

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FIGURE 3-5
VACUUM EXTRACTION EQUIPMENT LAYOUT
REMEDIAL TECHNOLOGY HANDBOOK
BADGER ARMY AMMUNITION PLANT

ABB Environmental Services, Inc.

Potential Impact to Public Health and the Environment. Potential impacts would be dependent on the method used to treat vapors produced by the process. Dispersion of vapors into the atmosphere could result in localized concentrations of contaminants in the vicinity of the wellheads. Administrative controls could be used to limit access to those areas. If carbon adsorption or thermal destruction are used to treat vapors, emissions of contaminants or treatment byproducts to the atmosphere would be minimal.

Secondary Waste Management Requirements. Emissions from SVE are wastewater and air emissions (type and quantity of air emissions are dependent on what method of vapor treatment is used). The wastewater requires further treatment and/or off-site disposal. Air emissions could be significant if dispersion is used but minimal if carbon adsorption or thermal destruction are used. Spent carbon would require regeneration or disposal off site.

Technical Feasibility and Reliability. SVE is technically feasible for removal of VOCs from soil. The process works most effectively on VOCs with a high vapor pressure and low water solubility. The process has been proven to reliably meet specified cleanup goals in many different hydrogeologic settings (e.g., clays, silts, and sands and gravel).

Downtime for equipment maintenance or servicing would be largely a function of the methods used for vapor and/or wastewater treatment.

Demonstrated Performance. The process has been demonstrated full-scale at Superfund, industrial, and petroleum sites. Target contaminants at each of the sites were VOCs. Initial recovery rates of VOCs from subsurface soils have been as high as 2,000 lbs/day (USEPA, 1989). Contaminants have been recovered from clay, rock, sand, and silt subsurface soils. The longest known remediation effort is 2.5 years.

Availability of Technology and Related Services. Equipment and services for SVE are readily available. The extraction portion of the process uses off-the-self components (i.e., blowers and vapor/liquid separators). Installation of an extraction system could be accomplished by drilling and HVAC contractors. However, an experienced vendor would be required for design of a complete system because placement of extraction wells and specification of vacuum requirements are critical to the effectiveness of a system. Terra Vac, Inc. has considerable experience in design, construction, and operation of SVE systems.

Monitoring and Maintenance Requirements. Soil, air emissions, and wastewater must be monitored during remediation. Analysis of soil borings taken during system operation is required to establish a site-specific relationship between the concentrations of contaminants at the wellhead and the concentrations of contaminants in the soil. Once the air/soil relationship is established, air monitoring at the wellhead will effectively monitor the progress of soil remediation. Air monitoring is also required to ensure compliance with emission limits set by operating permits. Final soil borings must be taken and analyzed to confirm that soil cleanup levels have been attained. Wastewater monitoring is required to ensure compliance with discharge permits.

Treatability Studies. Although treatability studies are not required for SVE, testing prior to design is required to determine soil permeability to vapor flow, vapor concentrations, and aquifer characteristics (USEPA, 1991). Soil permeability and vapor concentrations would be determined during an air permeability test. Testing would consist of removing vapors at a constant flow rate from an extraction well, while monitoring with time the transient subsurface pressure distribution at fixed points. Vapor samples would be taken at the beginning and end of the air permeability test, the duration of which would be long enough to extract at least one pore volume of vapor from the contaminated soil zone.

Groundwater pump tests would determine the water table drawdown that may be necessary to counteract the water upwelling effect resulting from decreased vapor pressure in the vicinity of an extraction well. Water table drawdown could also be used to expose contaminated soil which is normally below the water table. If the water table drawdown is maintained, the soils could be remediated by SVE.

Capital Costs. Capital costs for SVE are included in a unit cost per ton of soil. The cost associated with the installation of the extraction system are relatively minor as compared to the costs of monitoring and vapor and wastewater treatment.

Indirect capital costs include engineering, permit applications, and administrative costs. Permitting and administrative expenses and engineering services each may range between 5 to 10 percent of capital costs.

Operation and Maintenance Costs. O&M of SVE includes costs associated with utilities, labor, supplies, residuals disposal, monitoring, and administrative support. O&M costs are included in the unit cost. For a large site at which no offgas treatment is required and no wastewater is generated, the cost of remediation could

be as low as $10 per ton. Based on actual cost information from two Superfund sites, the unit cost can range between $30 and $70 per ton, largely dependent on the size of the site and treatment requirements for vapor and wastewater.

Cost Sensitivity. The costs of SVE are sensitive to the following factors:

- Size of Site. A large site gives the process the benefit of economy of scale. The unit cost will decrease with a larger site.

- Type of Soil. It is generally believed that sandy soils will take less time to remediate than clay soils. However, sufficient air-filled porosity is the critical factor.

- Nature of Contamination. The volatility and the Henry's Law Constant of a contaminant have a great effect on the time required to remediate a site. A contaminant with a high value of Henry's Law Constant will take a shorter time to extract than will one with a low value.

- Amount of Contamination. If offgas treatment is required (e.g., activated carbon), the higher carbon costs for the more contaminated site will increase the overall remediation cost.

- Requirements for Offgas Treatment. Some sites will require only dispersion stacks for the offgas, depending on the concentration and toxicity of the contaminant. If offgas treatment is required (e.g., in the form of activated carbon), this can amount to as much as 30% of the unit cost of the remediation.

- Wastewater Generation Possibilities. If little or no water is recovered from the vadose zone, the unit cost may be up to 20% lower than for a site with large amounts of water.

Summary. The major advantages and disadvantages of SVE are summarized in Table 3-7.

3.7.3 Potential Site Applicability.

SVE can be used to treat soil contaminated with VOCs. Application of this technology may be practical at the Propellant Burning Ground.

TABLE 3-7
EVALUATION CRITERIA SUMMARY: IN SITU VACUUM EXTRACTION

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Air is injected or flows into subsurface soils at locations around a spill site, and volatile organics are withdrawn under vacuum from extraction wells. Vapors are either dispersed into the atmosphere or are treated by carbon adsorption or thermal destruction.

EFFECTIVENESS	IMPLEMENTABILITY	COST
Advantages	Advantages	Advantages
• Removes contaminants from unsaturated soil	• Technology has demonstrated attainment of cleanup levels at hazardous waste sites contaminated with volatile organics	• Unit costs range $30-$70/ton
• Effective for the removal of volatile organics	• Extraction equipment is off-the-shelf	
• Demonstrated capability for extracting up to 2,000 lbs of volatile organics per day	• Experienced vendors are readily available	
• Vapors can be treated after extraction	• Treatability studies are not necessary	
Disadvantages	Disadvantages	Disadvantages
• Dispersion of vapors could result in localized concentrations of contaminants near well heads	• Extensive vadose zone and aquifer investigations are required	• Costs are sensitive to soil moisture content
• Carbon used for treatment requires regeneration/disposal	• Extensive soil, air, and wastewater monitoring required, including soil borings to monitor and verify attainment of soil cleanup levels	• Costs are sensitive to vapor treatment requirements
• Wastewater requires treatment		
• Not effective for treating soil with a high moisture content		

4.0 WATER TREATMENT TECHNOLOGIES

As with soil and sediment, selection of an appropriate remedial technology for groundwater depends on contaminant types and concentrations, as well as the volumes of water to be treated. The FS report will summarize the nature and distribution of groundwater contamination for each site at BAAP along with groundwater remedial objectives. The following paragraphs briefly describe sitewide groundwater contamination.

BAAP activities that result in soil and sediment contamination (i.e., burning of solvents, solvent-containing wastes, propellants, explosives- and propellant-contaminated wastes, and disposal of manufacturing process waters) have also contributed to groundwater contamination. Groundwater contamination resulting from these activities occurred and presumably still occurs through continued leaching of chemicals from soil. Soluble compounds such as trichloroethylene (TRCLE) are mobilized from soil by precipitation events and travel through the soil column to groundwater.

Contaminant types and concentrations detected in groundwater vary across BAAP. Predominant contaminants include VOCs, DNTs, NIT, SO4, and some low levels of metals (i.e., chromium [CR], PB, and cadmium [CD]).

The principal VOCs detected in groundwater at a number of sites include carbon tetrachloride (CCL4), TRCLE, chloroform (CHCL3), and 1,1,1-trichloroethane (111TCE). Concentrations of CCL4 ranged from below detection limits to 97 micrograms per liter ($\mu g/\ell$), TRCLE from below detection limits to 92 $\mu g/\ell$, CHCL3 from below detection limits to 83.5 ($\mu g/\ell$), and 111TCE from below detection limits to 59.3 $\mu g/\ell$. Although concentrations of these compounds are in the $\mu g/\ell$ range, they frequently exceed Wisconsin Enforcement Standards for CCL4 (5 $\mu g/\ell$), TRCLE (5 $\mu g/\ell$), and CHCL3 (6 $\mu g/\ell$). The Enforcement Standard for 111TCE (200 $\mu g/\ell$) was not exceeded in any of the wells sampled.

SVOCs detected in groundwater at BAAP consisted primarily of 26DNT, reported in concentrations from below detection limits to 2.17 $\mu g/\ell$. The Wisconsin Enforcement Standard for 26DNT is 0.05 $\mu g/\ell$. 26DNT may present a risk to public health primarily through ingestion of groundwater.

Inorganics detected in groundwater that may pose a risk to public health include NIT and SO4. NIT, which has an Enforcement Standard of 10,000 $\mu g/\ell$, ranged in concentration from below detection limits to 27,000 $\mu g/\ell$. SO4 has an Enforcement Standard of 250,000 $\mu g/\ell$ and ranged in concentration from below detection limits to 15,000,000 $\mu g/\ell$. Most metals in groundwater were detected at low levels (i.e., less than 50 $\mu g/\ell$) and concentrations did not exceed Enforcement Standards. Remedial technologies were evaluated for treatment of inorganics as well as for pretreatment to prevent fouling of organic treatment operations.

Water treatment technologies may also be applicable for treating potentially contaminated surface water at BAAP or for secondary wastes generated from soil treatment.

Water treatment technologies applicable to treatment of various contaminants and wastestreams (primarily groundwater) at BAAP are evaluated in the following subsections. Each technology is evaluated for technical, cost, and institutional considerations associated with potential remedial measures. The need for treatability study investigations is discussed as well as potential site applicability. Detailed site-specific contamination assessments, remedial objectives, and extraction schemes are described and discussed in the FS report.

4.1 AIR STRIPPING

This subsection describes the air-stripping method.

4.1.1 Description

Air stripping is a method frequently used to remove VOCs from wastewater and groundwater. During the air-stripping process, contaminated water is contacted with large volumes of clean air. Contaminants are transferred from the liquid phase to the gas phase, and carried off with effluent air. Air strippers are commonly found at groundwater clean-up sites, municipal water supply treatment plants, and industrial wastewater treatment plants.

Several air-stripping methods can be used. In a packed tower (the most common air-stripping method), air and water flow countercurrent. Contaminated water enters from the top of a column and trickles down through packing material, forming a thin film of water on the surface of the packing. This creates a large liquid surface area

for the transfer of contaminants from the liquid to vapor phase. Air is supplied to the base of the column and moves upward. Effluent air exits through the top of the column, while effluent water exits from the base. A cross section of a packed tower air-stripping unit is shown in Figure 4-1.

Depending on desired clean-up levels, as well as national and local regulations, effluent air may have to be treated to remove contaminants before being released to the atmosphere. This can be accomplished by adding a carbon adsorption unit, catalytic incinerator, flare, or thermal incinerator. Carbon adsorption units are most commonly used for vapor treatment.

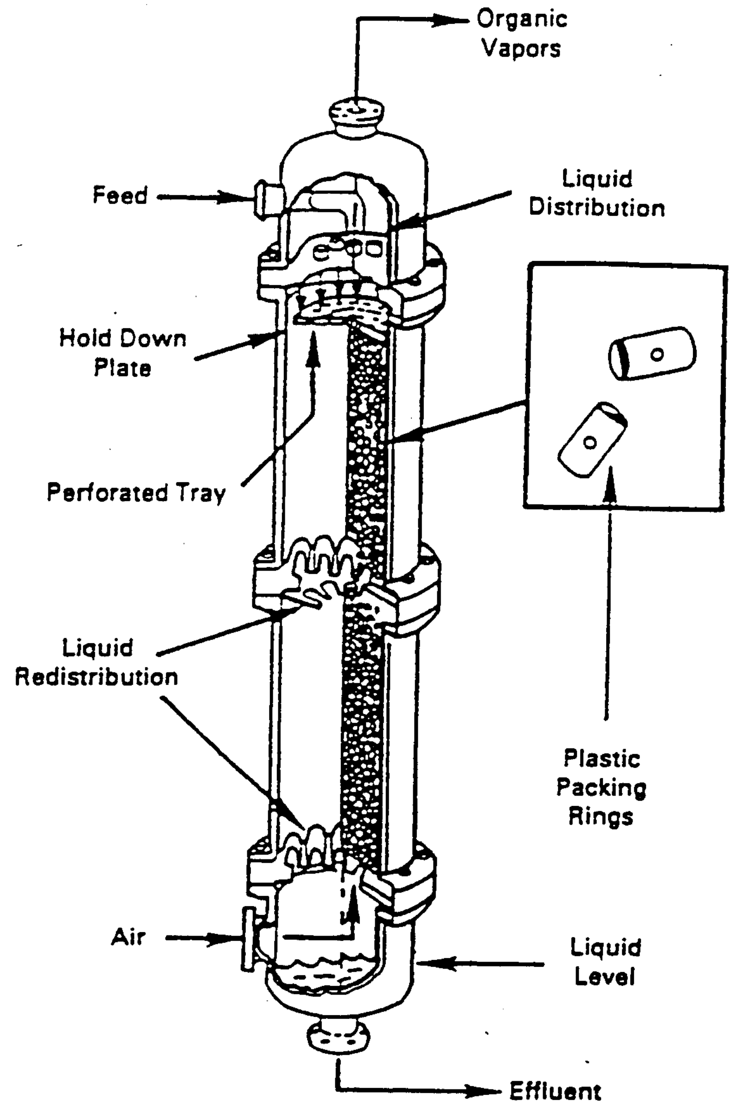
If the contaminated water contains compounds that cannot be volatilized in the process, further treatment may also be required for the stripper effluent water.

4.1.2 Technology Assessment

Reduction in Toxicity, Mobility, and Volume. Air stripping substantially reduces the volume of contaminated groundwater because contaminants are transferred to the gas phase. Removal efficiency varies with the volatility and concentration of the contaminant. For VOCs, removal rates greater than 99 percent have been demonstrated. The remedy is permanent if air stripping is used in conjunction with a vapor-phase treatment that treats contaminants in air-stripper emissions.

Treatment Time. Because air stripping is a simple and widely used technology, equipment is easy to obtain or construct; this minimizes initial implementation time. Several firms market standard air-stripping towers for specific flow rates. Air-stripping towers capable of treating 1,000 gallons per minute (gpm) are currently operated. If carbon units are required to treat effluents, they can also be easily obtained. Multiple units may be used in parallel to increase the flow rate of the treatment stream. Alternatively, the units may be operated in series to increase contaminant removal efficiencies.

Potential Impact to Public Health and the Environment. The two effluents from the process (treated water and air emissions) may pose a risk to public health and the environment. If the water to be treated contains contaminants that cannot be treated by air stripping, these contaminants will remain in the effluent. Air emissions from the process may also exceed federal and/or local standards. Treated water and air may receive secondary treatment to bring effluent concentrations within regulatory



SOURCE: U.S.EPA ALTERNATIVE TO HAZARDOUS WASTE LANDFILLS, 1986

FIGURE 4-1
PACKED COLUMN AIR STRIPPING UNIT
REMEDIAL TECHNOLOGY HANDBOOK
BADGER ARMY AMMUNITION PLANT

limits. Risks posed by a properly implemented and maintained air-stripping operation are insignificant.

Secondary Waste Management Requirements. Requirements for secondary waste treatment arise when effluent water and/or air require further treatment, or when scale forms inside the air stripper. If carbon adsorption units are used for secondary treatment, spent carbon must be disposed of or regenerated. Scale removed from air-stripping units may need to be treated before disposal.

Technical Feasibility and Reliability. Air-stripping systems are feasible for on-site pretreatment when large volumes of contaminated water and groundwater require treatment. Air stripping is suitable for the treatment of water with high concentrations of VOCs, ammonia, and some SVOCs (i.e., those with total concentrations greater than 100 ppm). However, concentrated organics extracted by secondary treatment must be disposed of, and tower off-gases may require treatment (i.e., scrubbing) to meet local and federal air quality standards.

Influent restrictions to an air-stripping system may dictate pretreatment prior to stripping. High influent concentrations of metals such as iron (FE), manganese (MN), CD, or magnesium (MG) that would oxidize and cause scaling or fouling of the tower may need to be reduced before air-stripping. For wastewater containing high concentrations of calcium (CA), an inhibiting polymer may be added to ease the fouling problem. Acid-wash systems can be used to solubilize the scale in a continuous or batch-flow tower. Pretreatment may be required for wastewater streams containing large amounts of suspended solids and oils and greases, which may also accumulate in the air stripper and cause fouling.

Air-stripping towers currently process VOCs, trihalomethanes, and ammonia (NH4)-contaminated water at hazardous waste sites, manufacturing facilities, and municipal water treatment plants. On-site facilities have proven successful for a broad range of contaminants and flow rates. Due to the nature of the air-stripping process, a consistent-quality effluent can be obtained, provided there are no large increases in influent concentrations or irreversible tower fouling.

Demonstrated Performance. Air stripping has been used for nearly 40 years in industrial processes, and more recently for the removal of VOCs, NH4, and some SVOCs from groundwater. Air stripping has been used successfully at the Triangle Chemical and Verona Wellfield Superfund sites and is currently operated at the BAAP Propellant Burning Ground under the Interim Remedial Measures (IRM)

Plan to treat groundwater at the site. The unit, designed by Calgon Corporation (Calgon), is used in conjunction with a carbon adsorption unit. Groundwater is first treated using a carbon unit and is subsequently treated using an air-stripping unit.

Availability of Technology and Related Services. Air-stripping units are often customized for a particular site. However, because the technology is relatively simple and materials readily available, air-stripping units may be constructed quickly and easily. Several vendors currently market air stripping units.

Monitoring and Maintenance Requirements. The following parameters should be monitored to evaluate the efficiency and proper operation of an air-stripping unit:

- contaminant levels in influent and effluent water to evaluate removal rates and determine if further treatment is required
- contaminant levels in effluent air to determine whether federal or local standards are being exceeded and if further treatment is required
- water and air feed rates to maintain optimal performance (air-to-water ratios are critical to removal efficiencies of the air stripper)
- pressure drop across the tower as an indicator of fouling

Because the technology is relatively simple, maintenance requirements for air strippers are minimal. If the stripper becomes fouled by scale, oil, grease, or solids, cleaning may be required. Other maintenance requirements may be imposed if secondary treatment is necessary (e.g., carbon from adsorption units may need to be regenerated or replaced).

Treatability Studies. Treatability studies are not required to determine the effectiveness of air stripping because of the demonstrated performance of the technology to treat VOCs detected in BAAP groundwater. However, pilot-scale investigations to determine the most efficient system combination (e.g., air stripping with vapor-phase carbon or aqueous-phase carbon with air stripping) are anticipated.

Capital Costs. Factors affecting capital costs of air-stripping units include the type of contaminant, contaminant concentration, groundwater temperature, target treatment levels, seasonal temperature variation, and flow rates. Accurate cost estimates can only be determined when the values for these variables are known.

The following equipment was included when establishing cost estimates for air strippers:

- tower with two pumps, blower, and piping
- concrete slab
- basic instrumentation (i.e., gauges)
- flow and pressure recorder controllers
- feed tank

Removal rates were considered to be 99.5 percent for influent concentrations of 1,000 parts per billion of TRCLE.

Capital cost estimates for air-stripping units are as follows:

Flow Rate (gpm)	Capital Cost ($)
10	90,000
30	90,000
100	350,000
300	530,000
1,000	690,000

Operation and Maintenance Costs. O&M costs also vary with the variables listed in the capital cost subsection. To establish O&M cost estimates, the following assumptions were made:

- Labor required for operation is 8 hours per week for units with flow rates less than or equal to 100 gpm, and 16 hours per week for units with flow rates greater than 100 gpm.

- Electricity is included.

- No pretreatment or post-treatment is required.

O&M costs for the various units are as follows:

Flow Rate (gpm)	O&M Cost Per Year ($)
10	25,000
30	27,000
100	45,000
300	96,000
1000	136,000

Cost Sensitivity. Air-stripper costs depend on the variables listed in the capital cost subsection. Equipment requirements and costs can be more accurately determined through pilot-scale tests and further refined through system design.

Summary. The major advantages and disadvantages of air stripping are summarized in Table 4-1.

4.1.3 Potential Site Applicability

Air stripping can be used to treat groundwater contaminated with volatile compounds. Application of this technology may be practical for groundwater treatment at the Propellent and Deterrent Burning Grounds.

4.2 CARBON ADSORPTION

This subsection describes the carbon adsorption process.

4.2.1 Description

Activated carbon adsorption is a physical separation process in which organic and inorganic materials are removed from wastewater by sorption (i.e., the attraction and accumulation of one substance on the surface of another). As water passes through the porous granules of the carbon, contaminant molecules are attracted to the surface of the pores and held there by weak physical forces. Traditionally, activated carbon has been used to remove undesirable odors and colors in drinking water, or to aid in treatment of wastewater. An important aspect of carbon adsorption is its capability of removing organics that are not completely removed by conventional biological treatment. Activated carbon can be used to (1) reduce chemical oxygen

TABLE 4-1
EVALUATION CRITERIA SUMMARY: AIR STRIPPING

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Contaminants are contacted with large volumes of clean air. The contaminants are transferred from the liquid phase to the gas phase, and carried off with the effluent air.

EFFECTIVENESS	IMPLEMENTABILITY	COST
Advantages	Advantages	Advantages
• Reduces the volume of contaminated groundwater	• Standard equipment is used	• IRM unit is already in operation at the Propellant Burning Ground
• VOC removal rates greater than 99% have been achieved with air stripping	• Equipment is readily available	• Maintenance costs are comparable to other groundwater treatment technologies
• Suitable for most volatiles and some semivolatile organic compounds	• Has been used by industry for 40 years	
• Strippers may be used in parallel to increase treatment rates	• Well-demonstrated at hazardous waste sites	
• Consistent quality effluent can be produced	• Many companies design, construct, install, and operate air strippers	
	• Maintenance requirements are minimal	
Disadvantages	Disadvantages	Disadvantages
• Effluent air and water may have to be treated to remove remaining contaminants	• Maintenance requirements are significantly greater if strippers are quickly fouled by scale or if pretreatment and/or post-treatment is required	• Costs increase significantly if pre- or post-treatment is required
• Contaminants are not treated, but transferred from liquid state to gaseous phase	• Wisconsin air emission standards and permitting requirements must be met.	
• Pretreatment of influent water may be required to remove metals, calcium, or oils and greases that may cause fouling		
• If carbon units are used for effluent air treatment, spent carbon has to be replaced or regenerated		
• Stripping is usually not effective on contaminants that are not volatile compared to water		

Notes:

IRM - Interim Remedial Measures
VOC - Volatile Organic Compound

demand, biochemical oxygen demand, and other related parameters; (2) remove toxic and refractory organics; (3) remove and recover certain organics; and (4) remove selected inorganic chemicals including some heavy metals from wastewater. Most dissolved organics can be adsorbed by carbon.

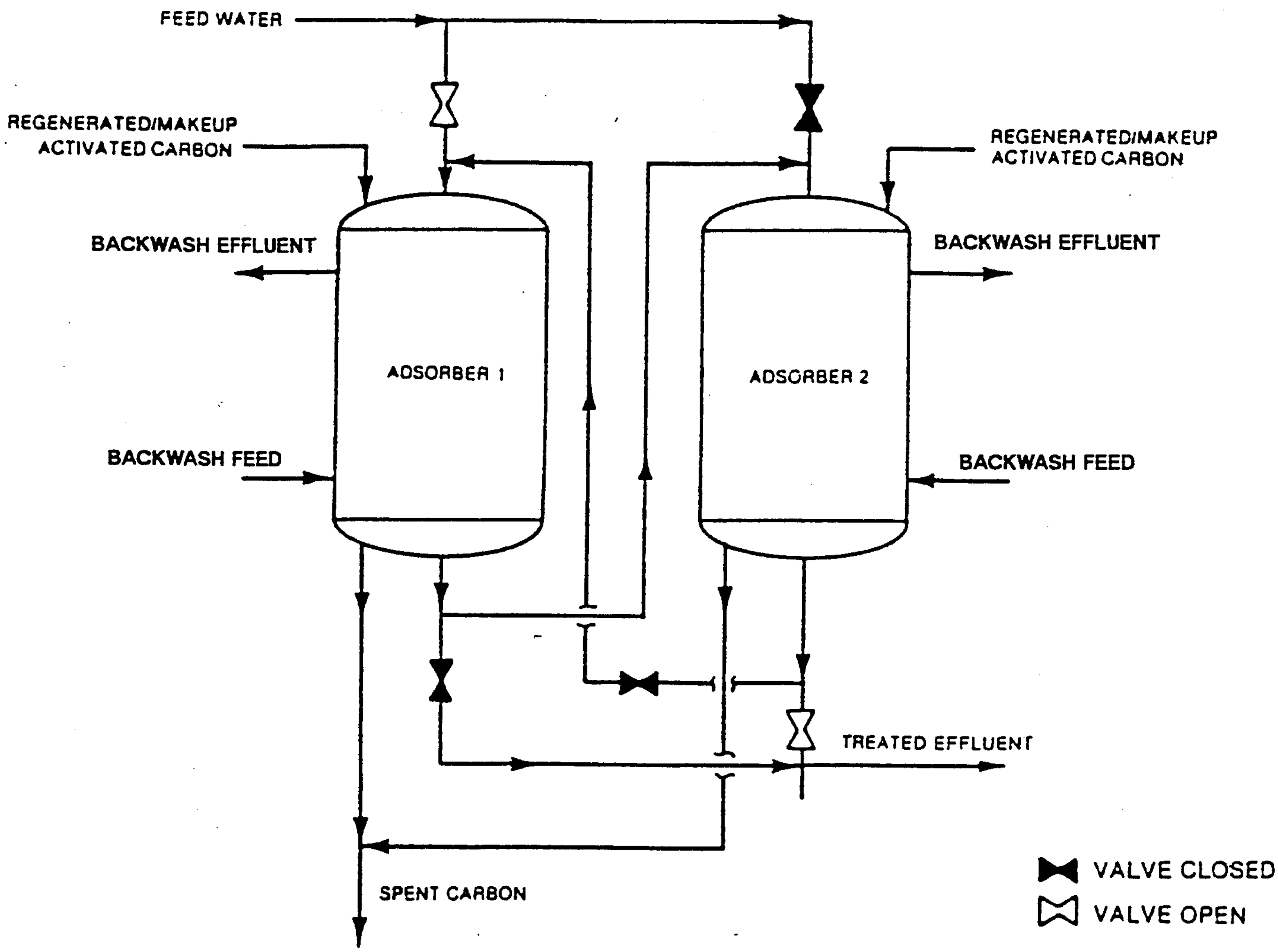
Much of the surface area available for adsorption by carbon is found in the pores within the carbon particles created during the activation process. A controlled process of dehydration, carbonization, and oxidation of raw materials (e.g., coal, wood, coconut shells, and petroleum-based residues) yields the activated carbon. As activated carbon adsorbs molecules or ions from wastewater, the carbon pores eventually become saturated, and the exhausted carbon must be regenerated for reuse or replaced with fresh carbon. The adsorptive capacity of the carbon can be partially restored by chemical or thermal regeneration. However, carbon saturated with explosive contaminants may not be able to be regenerated and may have to be disposed of.

Carbon treatment can be accomplished by using granular activated carbon (GAC) in expanded upflow, packed upflow, or downflow contacting systems. Most hazardous waste treatment applications involve the use of several downflow adsorption units connected in series.

Expanded (i.e., fluidized bed) upflow columns operate under forced flow to expand the carbon bed volume of the column by 10 percent. Expanded upflow beds typically use 8-by-30 mesh carbon, which can be recharged during operation. Packed upflow beds remain fixed within the column. Periodically, exhausted carbon is removed from the bottom of the column, and virgin or regenerated carbon is added at the top. Packed beds generally use 8-by-30 mesh carbon and require an influent of low turbidity.

Downflow configurations use fixed beds, with complete replacement of the column at breakthrough or at some other pre-determined level. (Breakthrough occurs upon detectable levels of the target pollutant in the effluent.) Multistage operations (i.e., series or parallel connections) provide more efficient use of activated carbon than single-stage configurations.

In a typical downflow fixed bed operation, two columns are operated in series and a spare column is held in reserve. Figure 4-2 shows a series operation of two downflow columns, including the sampling port between the columns used to monitor the effluent concentration of the lead column. When breakthrough or some other



SOURCE: PROCESS DESIGN MANUAL FOR ACTIVATED CARBON ADSORPTION

FIGURE 4-2
TWO-VESSEL GRANULAR CARBON ADSORPTION SYSTEM
REMEDIAL TECHNOLOGY HANDBOOK
BADGER ARMY AMMUNITION PLANT

pre-determined level is reached in the effluent of the lead column, it is removed from service for carbon disposal or regeneration. The second column becomes the lead column, and the spare column is added as the second column in the series. When breakthrough or some other predetermined level is again reached, the cycle is repeated.

4.2.2 Technology Assessment

Reduction in Mobility, Toxicity, and Volume. Carbon adsorption reduces the mobility of wastewater constituents by a surface attraction phenomenon. Constituents are physically held to internal or external surfaces of the carbon granules by surface tension. This bonding removes organic and inorganic species from the wastewater stream, immobilizing them within the carbon bed. However, the process concentrates contaminants within the carbon bed, increasing toxicity of the carbon.

Treatment Time. Single units can process up to 700 gpm. Higher flow rates can be accommodated using multiple units in parallel connections. Contact times range from 10 minutes to just over an hour for $\mu g/\ell$ influent concentrations, and 30 minutes to several hours for milligrams-per-liter (mg/ℓ) concentrations.

Initial column tests to determine carbon usage and system design take a few days to a few weeks, depending on the test method used. Mobilization and start-up take less than a week because units are completely mobile and self-contained. Mobilization consists of minor plumbing connections. Once full-scale operation is initiated, treatment could take several years, depending on the volume of the contaminant plume and mitigation of sources.

Potential Impact to Public Health and the Environment. If not properly contained and controlled, concentrated organics in the spent carbon are a potential public health and environmental hazard. The treated groundwater effluent would still contain residual concentrations of contaminants and would have to meet National Pollutant Discharge Elimination System (NPDES) permit requirements to be discharged to surface water or groundwater, or pretreatment standards to be discharged to a publicly-owned treatment works.

Secondary Waste Management Requirements. The spent carbon would contain waste constituents removed from the wastestreams. The carbon must be either regenerated off-site or disposed of in a secure landfill (carbon with PCBs or dioxin

are not currently regenerated by the vendors). Thermal regeneration of the used carbon is the most common method currently used but may not be feasible if the carbon is saturated with explosive contaminants. Other methods of regeneration are solvent and steam regeneration.

Periodic backwashing of the carbon would require holding tanks for the backwash. Often the backwash is allowed to settle and the liquid portion is sent back through the carbon. The small amount of sludge generated during settling contains a high concentration of organics and requires disposal (USEPA, 1986a).

Technical Feasibility and Reliability. Because carbon adsorption is essentially a physical attraction phenomenon, the polarity of the waste compounds will largely determine the effectiveness of the adsorption process. Highly polar molecules cannot be effectively removed by carbon adsorption. Another factor affecting the effectiveness of carbon adsorption is aqueous solubility. The more hydrophobic (insoluble) a molecule is, the more readily the compound is adsorbed. Low-solubility humic and fulvic acids can sorb to activated carbon more readily than most waste contaminants, resulting in rapid carbon exhaustion (USEPA, 1985b).

Carbon adsorption is applicable to most nonpolar organics and some metals and inorganics, including antimony (SB), arsenic (AS), bismuth, CR, tin, silver (AG), mercury (HG), cobalt, zirconium, chlorine, bromine, iodine, nitrogen, chlorides, sulfates, sulfur dioxide, hydrogen sulfide, and NH4.

The ability of carbon adsorption to consistently remove groundwater contaminants to $\mu g/\ell$ concentrations is well-documented. Rule-of-thumb guidelines for reliable operations are maximum influent contaminant concentrations of 10,000 mg/ℓ, suspended solids less than 50 mg/ℓ, and oil and grease less than 10 mg/ℓ.

Demonstrated Performance. Carbon adsorption is a well-established technology, and has been applied consistently to treat contaminated groundwater to below detectable limits. Table 4-2 lists results obtained by Calgon from 31 operating plants that used carbon to treat groundwater. The IRM Plan being followed at the BAAP Propellent Burning Ground uses a carbon adsorption unit to treat groundwater at the site. The carbon adsorption unit, designed by Calgon, is a Calgon Model 10 Non-Backwash Adsorber System. The unit is designed to handle an average influent flow of 250 gpm with a maximum capacity of 400 gpm.

TABLE 4-2
EFFLUENT CONCENTRATIONS ACHIEVED WITH CARBON IN 31-PLANT STUDY

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ORGANIC COMPOUNDS IN GROUNDWATER	NUMBER OF OCCURRENCES	INFLUENT CONCENTRATION RANGE	CARBON EFFLUENT CONCENTRATION ACHIEVED
Carbon tetrachloride	4	130 μg/L-10 mg/L	<1 μg/L
Chloroform	5	20 μg/L-3.4 mg/L	<1 μg/L
DDD	1	1 μg/L	<.05 g/L
DDE	1	1 μg/L	<0.05 μg/L
DDT	1	4 μg/L	<0.05 μg/L
Cis-1,2-dichloroethylene	8	5 μg/L-4 mg/L	<1 μg/L
Dichloropentadiene	1	450 μg/L	<10 μg/L
Diisopropyl ether	2	20-34 μg/L	<1 μg/L
Tertiary methyl-butylether	1	33 μg/L	<5.0 μg/L
Diisopropyl methyl phosphorate	1	1,250 μg/L	<50 μg/L
1,3-dichloropropene	1	10 μg/L	<1 μg/L
Dichloroethyl ether	1	1.1 mg/L	<1 μg/L
Dichloroisopropyl ether	1	0.8 mg/L	< μg/L
Benzene	2	0.4-11 mg/L	<1 mg/L
Acetone	1	10-100 μg/L	<10 mg/L
Ethyl acrylate	1	200 mg/L	<1 μg/L
Trichlorotrifluoroethane	1	6 mg/L	<10 μg/L
Methylene chloride	2	1-21 mg/L	<100 μg/L
Phenol	2	63 mg/L	<1 μg/L
Orthochlorophenol	1	100 mg/L	<1 mg/L
Tetrachloroethylene	10	5 μg/L-70 mg/L	<1 μg/L
Trichloroethylene	15	5 μg/L-16 mg/L	<1 μg/L
1,1,1-trichloroethane	6	60 μg/L-25 mg/L	<1 μg/L
Vinylidene chloride	2	5 μg/L-4 mg/L	<1 μg/L
Toluene	1	5-7 mg/L	<10 μg/L
Xylene	3	0.2-10 mg/L	<101 μg/L

Notes:

DDD - dichlorodiphenyldichloroethane
DDE - dichlorodiphenyldichloroethylene
DDT - dichlorodiphenyltrichloroethane
mg/L - milligrams per liter
μg/L - micrograms per liter

SOURCE: O'Brien and Fisher, 1983

Availability of Technology and Related Services. Many commercial service companies, as well as vendors, supply mobile carbon adsorption systems. Mobile units vary in size from 2,000 to 40,000 pounds of carbon, with a capacity of 10 to 600 gpm. Currently, no commercial mobile regeneration units are available (USEPA, 1986a). USEPA has a mobile emergency environmental response unit that contains three sand filters followed by three GAC columns in series. The system has been used at more than 20 sites.

Monitoring and Maintenance Requirements. Periodic effluent sampling is required to assess the breakthrough point. For two GAC columns in series, samples are taken from the influent entering the final column. When the first column reaches breakthrough or some other pre-determined level, it is taken off-line and serviced.

The most obvious maintenance consideration associated with GAC treatment is regeneration of spent carbon for reuse. Regeneration would be performed for each column at the conclusion of its bed-life. If regeneration is not feasible because of explosives, PCB, or dioxin contamination, the spent carbon must be disposed of in a secure landfill. Other O&M requirements for the GAC technology are minimal if appropriate automatic controls have been installed (USEPA, 1985b).

Treatability Studies. Isothermal tests to determine the feasibility of GAC for treating explosive-contaminated groundwater (primarily DNTs) have been performed by Roy F. Weston, Inc. In addition, a treatability study was performed by Calgon as part of the IRM to estimate removal of VOCs and DNTs in BAAP groundwater (Calgon Carbon Corporation, 1989). Treatment using GAC was found to be effective; therefore, it is being used with air stripping at the site to treat groundwater. Pilot-scale investigations to determine the most efficient system combination (e.g., air stripping with vapor-phase carbon or aqueous-phase carbon with air stripping) are anticipated.

Capital Costs. Capital costs are described for two different configurations (i.e., permanently housed units and mobile units). For permanently housed units, the following costs are representative:

Flow Rate (gpm)	Capital Cost ($)
10-30	70,000
100	200,000
300	400,000
1,000	900,000

These costs assume pumps and piping are installed with 100 percent backup, carbon columns are sized to handle maximum possible flow rates, two carbon columns are used in series with one spare unit available, equipment is installed on a concrete pad, and valves are installed for effluent monitoring purposes.

Mobile units can be configured with either single or multiple pre-piped contactors. Costs associated with a mobile system include $30,000 for mobilization and start-up, including column tests; and $50,000 to $60,000 for a 2,000-pound-capacity unit; or $90,000 to $100,000 for a 10,000-pound-capacity unit.

Operation and Maintenance Costs. O&M costs for treating groundwater contaminated at $\mu g/\ell$ concentrations range from $0.25 to $0.55 per 1,000 gallons. For groundwater with mg/ℓ concentrations, costs range from $0.50 to $2.55 per 1,000 gallons. These costs reflect the amortization of equipment and carbon replacement.

Cost Sensitivity. Capital costs depend on contaminant concentrations in the wastestream and process flow rates. Capital costs will increase with increased flow rates and increased concentrations; that is, higher concentrations require longer residence times and larger equipment sizing, resulting in higher equipment costs. Capital costs also increase in cold-weather climates where buried piping, heating, and housing units are required.

O&M costs are highly dependent on carbon usage rate. Low usage rates (i.e., 0.1 pounds of carbon per 1,000 gallons of influent) can differ in cost by more than 100 percent from high usage rates (i.e., 10 pounds of carbon per 1,000 gallons of influent).

Summary. The major advantages and disadvantages of carbon adsorption are summarized in Table 4-3.

4.2.3 Potential Site Applicability

Carbon adsorption can be used to treat groundwater contaminated with certain organic and inorganic compounds. Application of this technology may be practical for groundwater treatment at the Propellent and Deterrent Burning Grounds.

TABLE 4-3
EVALUATION CRITERIA SUMMARY: CARBON ADSORPTION

REMEDIAL TECHNOLOGY HANDBOOK
BADGER ARMY AMMUNITION PLANT

Treatment by carbon adsorption involves contacting contaminated groundwater with granular activated carbon by flow through a series of packed-bed reactors. The activated carbon adsorbs organic and some metals and inorganics by a surface attraction phenomenon occurring within the internal pores of the carbon granulars.

EFFECTIVENESS	IMPLEMENTABILITY	COST
Advantages	Advantages	Advantages
• Immobilizes contaminants within the pores of the carbon	• High technical feasibility and demonstrated performance	• IRM unit is already in operation at the Propellant Burning Ground
• Continued pumping and carbon treatment reduces volume of contaminated groundwater plume	• Isotherm pilots available for many compounds, including DNTs detected in BAAP groundwater	
• Single units can accommodate flow rates up to 700 gpm; parallel units are used for higher rates	• Self-contained and mobile units available	
• Quick start-up times: typically less than 1 week	• Several experienced vendors to provide equipment and services	
• Effectively treats most nonpolar organics and various metals and inorganics	• Minimal operations and maintenance requirements; system operates unattended	
• Well-documented for groundwater applications even at microgram per liter concentrations		
Disadvantages	Disadvantages	Disadvantages
• Does not destroy contaminants, only concentrates them	• Mobile regeneration equipment not available; regeneration must be done off-site	• High operating costs largely due to the cost of the carbon
• Waste carbon is considerably more toxic than influent water; special disposal, regeneration, or destruction is required	• Effluent sampling required to assess breakthrough	• Carbon saturated with explosive contaminants may have to be disposed of and must comply with Land Ban regulations
• Cannot remove all contaminants; residuals will remain in effluent stream	• Standby unit must be available during change-out of spent column	
	• Pretreatment may be required for suspended solids, oil, or grease	

Notes:

BAAP - Badger Army Ammunition Plant
DNT - dinitrotoluene
gpm - gallons per minute
IRM - Interim Remedial Measures

4.3 PRECIPITATION AND FLOCCULATION

This subsection describes precipitation and flocculation processes.

4.3.1 Description

Chemical precipitation removes dissolved metals from aqueous wastes by chemically converting the metals to an insoluble form. Metals may be precipitated from solution as hydroxides, sulfides, carbonates, or other salts. This technology is used to treat aqueous wastes containing metals such as zinc (ZN), AS, copper, MN, HG, CD, trivalent CR, PB, nickel, barium, FE, SB, vanadium, thallium, and AG. Precipitation also removes organics that may be associated with suspended solids or metals. The process produces a metal sludge and a treated effluent that may require pH adjustment.

The most common precipitation processes are hydroxide, carbonate, soluble and insoluble sulfides precipitation, and potassium permanganate oxidation/precipitation. Hydroxide precipitation, the most common technique, uses alkaline agents as a source of hydroxide to raise the pH of wastewater to the optimum pH for precipitation. Metal ions subsequently precipitate as insoluble metal hydroxide. Principal sources of hydroxide are lime, hydrated lime, and caustic soda. Lime hydrolizes in water to form the hydroxide ion.

Carbonate precipitation may be used to remove metals either by direct precipitation or by converting hydroxides into carbonates using carbon dioxide. The principal sources of carbonate are sodium carbonate and calcium carbonate; however, calcium carbonate is ineffective in highly alkaline water.

Sulfide precipitation occurs when a metal and sulfide ion react to produce an insoluble metal sulfide. Two processes used to precipitate metal sulfides are (1) insoluble sulfide precipitation (ISP), in which sulfide is added as a slightly soluble iron sulfide slurry, and (2) soluble sulfide precipitation (SSP), in which sulfide is added as sodium sulfide or sodium hydrosulfide. With the SSP process, overdosing of sulfide compounds can produce toxic hydrogen sulfide gas; therefore, reaction tanks should be covered and vented.

Potassium permanganate oxidation/precipitation is commonly used for the removal of FE and MN from drinking water supplies. Addition of potassium permanganate to water high in soluble forms of FE and MN will oxidize the metals and produce

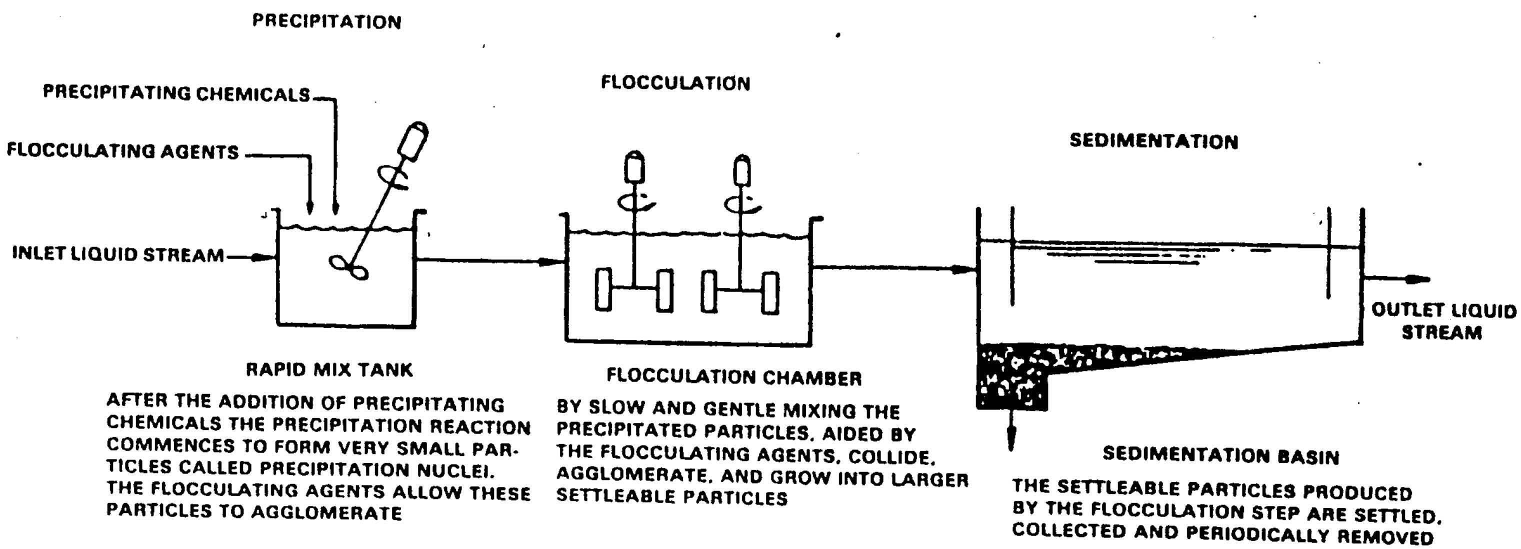
insoluble forms. Using a caustic agent, the pH of the solution is then adjusted to promote precipitation.

Flocculating agents can be added to precipitation processes to decrease the time required for particulates to settle out. These agents cause chemical changes that encourage small suspended particles to agglomerate into large particles that settle faster. During flocculation, the agent is added to the groundwater in a rapid mixing tank, agitated, and then transferred to a flocculation tank where slow mixing encourages particle contact. After mixing, the water is transferred to a settling basin, where the particles settle out. Common flocculants include lime, alum, iron salts, and organic agents (i.e., polyelectrolytes). A typical precipitation and flocculation system is shown in Figure 4-3.

4.3.2 Technology Assessment

Reduction in Mobility, Toxicity, or Volume. The volume of contaminated groundwater is significantly reduced because the contaminants are physically removed during the process. Metal concentrations can be reduced to levels of 0.01 to 0.5 ppm in the water. Higher reductions may be achieved with two-stage precipitation. However, the process produces a toxic heavy-metal sludge from which metals may be mobilized by a change in the chemical environment (e.g., a pH change). The waste volume is reduced from a large quantity of contaminated water to a significantly smaller volume of concentrated sludge. One factor that significantly affects the volume of sludge generated during the process is the type of precipitation agent used. An agent such as magnesium oxide produces a more compact sludge due to its propensity for insolubility and cementation, whereas iron sulfide used during the ISP process produces a large amount of sludge due to the addition of FE. One proprietary ISP process using iron sulfide produces almost three times more sludge than the conventional hydroxide-precipitation process (Kim and Amodeo, 1983).

Treatment Time. The time requirements for implementation of precipitation and flocculation vary, depending on whether a mobile or fixed unit is used. Units constructed on-site have throughputs ranging from 4 to 2,000 gpm. The fixed units require about one year for design and construction. Mobile units have throughputs ranging from 3 to 200 gpm. Mobile units require approximately four to six months for delivery, installation, and start-up.



Source: USEPA, 1985b.

FIGURE 4-3
TYPICAL PRECIPITATION/FLOCCULATION SYSTEM
REMEDIAL TECHNOLOGY HANDBOOK
BADGER ARMY AMMUNITION PLANT

Potential Impact to Public Health and the Environment. The use of precipitation and flocculation to treat contaminated groundwater has little impact on public health or the environment. Some chemicals used in the process are skin irritants; however, simple dermal protection measures provide for safe handling. The heavy-metal sludge produced must be disposed of properly or receive further treatment to prevent remobilization of metals. Hydrogen sulfide gas and the pollution of treated groundwater with excess sulfide ions are potential byproducts of the SSP process if the addition of the sulfide precipitation agent is not carefully controlled. Hydrogen sulfide gas has a characteristically strong odor and can be toxic at low concentrations, potentially creating a hazardous environment around the treatment facility. No significant risks exist if the process is performed in a properly constructed and operated facility.

Secondary Waste Treatment Requirements. The treated groundwater may require further treatment for organics, suspended solids, oil, grease, and residual metals. Metal sludge requires dewatering and proper disposal. Before disposal, further treatment of the sludge, such as S/S, may also be necessary. If SSP is used, systems may be required to control hydrogen sulfide emissions to prevent odor problems.

Technical Feasibility and Reliability. Precipitation and flocculation is feasible for the removal of a wide range of heavy metals from groundwater. Heavy metals that can be removed by the process include ZN, CD, CR, copper, fluoride, PB, MN, and HG. Each technique operates under the same principle; however, each has advantages and disadvantages.

Hydroxide Precipitation.

Advantages of this process include the following:

- Certain chemicals for precipitation are available at low cost.
- Systems can be automated, minimizing operator time.
- Heavy metal ion concentrations can be effectively reduced.
- Flocculating additives are not required.

Disadvantages of the hydroxide precipitation process include the following:

- To ensure effective removal, pH must be strictly controlled near the optimal pH.
- Systems must be designed to allow adequate reaction times.
- Certain metals (e.g., CR, FE, and MN) must be reduced or oxidized prior to precipitation.
- If two or more metals are present, the optimal pH for removal may be different for each, thereby affecting removal efficiency.
- Precipitated metals can resolubilize if pH changes.
- Complexing agents (e.g., cyanide [CYN], ethylene-diamine-tetraacetic acid, and other chelating agents) may adversely affect removal if the wastestream is not pretreated to overcome these effects.
- Sludge may require further treatment before dewatering.

<u>Carbonate Precipitation</u>.

Advantages of this process include the following:

- Certain metals require lower pH values to initiate precipitation.
- Certain metals can be removed more effectively than by hydroxide precipitation.
- Generally a denser sludge is produced, which is easier to settle and dewater.

Carbonate precipitation disadvantages are similar to those of hydroxide precipitation. Metals can resolubilize, complexing agents can interfere with chemical reactions, and the sludge may require further treatment.

<u>Sulfide Precipitation</u>.

Advantages of the sulfide precipitation process, which includes ISP and SSP, are as follows:

- The process removes metal ions at pH as low as 2 to 3.

- Sulfides are highly reactive, thereby requiring less detention time.

- There is better sludge thickening and less leachability at pH 5 as compared with the hydroxide sludge.

The primary disadvantage of the sulfide precipitation process is that it is more expensive than other precipitation methods. The respective advantages and disadvantages of ISP and SSP, both of which comprise sulfide precipitation, are provided in the following paragraphs.

ISP.

Advantages of the ISP process are as follows:

- Combined ability of sulfide and ferrous ions to reduce hexavalent CR to the trivalent state under the same conditions as required for precipitation (Grosse, 1986).

- ISP effectively controls the level of dissolved sulfide at concentrations low enough to eliminate any detectable emission of hydrogen sulfide gas.

Disadvantages of the ISP process include the generation of a large amount of sludge due to the addition of FE.

SSP.

Advantages of the SSP process are as follows:

- Rapid precipitation of dissolved metals.

- Reduced volume of sludge generated during the process.

Disadvantages of the SSP process include hydrogen sulfide gas and excess sulfide ions in treated groundwater as potential byproducts of the process. Hydrogen sulfide gas and sulfide can be reduced by controlling the sulfide reagent dose or aerating after

reaction time. Housing and venting the process equipment controls hydrogen sulfide fumes.

Potassium Permanganate Oxidation/Precipitation.

Advantages of this process include the following:

- Potassium permanganate is a strong oxidant that converts FE and MN to insoluble forms.
- The process produces a dense floc that settles rapidly.
- The process results in high suspended solids removal.

Disadvantages of the Potassium Permanganate Oxidation/Precipitation process include the following:

- There is the potential for oxidizing trivalent CR to its hexavalent state.
- High concentration solutions of potassium permanganate are a dermal hazard.

Precipitation and flocculation are not effective for wastestreams containing organic contaminants. However, many treatment processes used for the removal of organic contaminants can be fouled by heavy metals and inorganics. Therefore, precipitation and flocculation may be used as pretreatment for processes such as air stripping, ultraviolet (UV)/ozonation, and UV/hydrogen peroxide. Pretreatment is one of the more common uses of precipitation and flocculation during remedial actions.

Overall, precipitation and flocculation are reliable technologies for removing heavy metals from groundwater. The equipment used is readily available and easy to use. System design is simple and may be inserted into more complex treatment systems.

Demonstrated Performance. Precipitation and flocculation are well-demonstrated technologies. Both are commonly used for removal of heavy metals in industrial and municipal wastestreams, as well as wastestreams from hazardous waste sites.

Availability of Technology and Related Services. Chemicals required for precipitation and flocculation are readily available. Equipment is also available, and

some manufacturers provide compact single treatment units that can be delivered to the site. Mobile units may also be obtained.

Monitoring and Maintenance Requirements. The oxidation/reduction potential and pH of the influent must be monitored constantly during the precipitation and flocculation process to determine proper rates of chemical addition. Each effluent must be monitored to determine both the effectiveness of the process and the need for further treatment. Maintenance of the system typically requires 5 to 10 percent downtime.

Treatability Studies. Due to the demonstrated performance of precipitation and flocculation, treatability investigations are not recommended. If, however, the technology is chosen as a remedial alternative, bench- and pilot-scale testing should be performed to evaluate the appropriate technique, system design, and operating parameters for groundwater at BAAP. The range of costs for the combination of bench- and pilot-scale tests is from $10,000 to $100,000.

Capital Costs. Capital costs of stationary units include mobilization/ demobilization, construction, and site preparation. Construction costs for these units range from $80,000 to $5 million.

Costs for mobile units are given in cost per unit volume and include both capital and O&M costs. The cost for using one of these units at a hazardous waste site is estimated at $.02 to more than $.10 per gallon. These costs do not include groundwater pretreatment, sludge disposal, or further treatment of sludge or groundwater.

Operation and Maintenance Costs. O&M costs for stationary units range from $21,000 per year for a 4-gpm unit to $92,000 per year for a 560-gpm unit. These costs include precipitation and flocculation chemicals and labor. These costs do not include groundwater pretreatment, sludge disposal, or further treatment of sludge or groundwater.

Cost Sensitivity. The cost of precipitation and flocculation use is influenced by the following factors:

- Heavy metal concentrations - the higher the levels of heavy metals, the more chemicals required for treatment.

- Local labor cost - the process requires constant monitoring and, therefore, significant labor costs.

Summary. The major advantages and disadvantages of precipitation and flocculation are summarized in Table 4-4.

4.3.3 Potential Site Applicability

The potential for using precipitation and flocculation as a groundwater treatment technology at the BAAP sites depends on several factors including the type and concentration of contaminants in groundwater, target clean-up levels, and the capability to treat and/or dispose of metals-containing sludge generated during the process. Some BAAP sites are contaminated by both inorganic and organic compounds. As inorganics tend to foul many organic treatment systems, precipitation and flocculation may be used as a pretreatment process. Where precipitation and flocculation groundwater treatment is possible, system design and/or operating parameters would differ from site to site. Precipitation and flocculation is not a treatment alternative at sites where groundwater is contaminated solely by excessive concentrations of organics. The technology is potentially applicable to the following BAAP sites:

- Propellant Burning Ground
- Deterrent Burning Ground
- Existing Landfill

4.4 ION EXCHANGE AND RESIN ADSORPTION

This subsection describes ion exchange and resin adsorption.

4.4.1 Description

Ion exchange is the process of exchanging selected dissolved ionic contaminants in a wastewater with ions held by the ion exchange material. Ion exchange resins are typically synthetic organic materials that contain ionic functional groups to which exchangeable ions are attached. Synthetic resins are capable of withstanding a range of temperature and pH conditions, have a high exchange capacity, and can be tailored to show selectivity to specific ions. The exchange process is reversible, making it possible to regenerate the resins by backwashing. Resin adsorption, as

TABLE 4-4
EVALUATION CRITERIA SUMMARY: PRECIPITATION AND FLOCCULATION

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Chemical precipitation removes dissolved metals from aqueous wastes by chemically converting the metals to an insoluble form. Metals may be precipitated as hydroxides, sulfide, carbonates, or other salts. Flocculating agents cause chemical reactions that encourage small suspended particles to agglomerate into large particles that settle faster.

EFFECTIVENESS	IMPLEMENTABILITY	COST
Advantages	Advantages	Advantages
• Metal concentrations in groundwater can be reduced to 0.01 to 0.5 ppm	• Mobile units are available	• Capital and operating costs are comparable to other groundwater treatment technologies
• Large volume of contaminated groundwater is reduced to a smaller volume of concentrated sludge	• Equipment is simple and easy to use	
• Effective pretreatment for other groundwater remediation processes	• Equipment is readily available	
•	• Systems can be designed to be inserted into complex treatment systems	
•	• Well-demonstrated; used to treat industrial and municipal wastestreams, as well as contaminated groundwater	
Disadvantages	Disadvantages	Disadvantages
• Heavy metal sludge is produced	• Relatively long detention times are required to allow settling	• As metal concentrations increase, costs increase because of the greater volume of treatment chemicals required
• Metals in sludge may be remobilized by a change in chemical environmental (e.g., pH) during the hydroxide process	• Chemical environment must be strictly controlled and monitored to maintain correct operating conditions	• Post-treatment requirements increase overall costs
• Metal sludge must be disposed of or receive further treatment		
• Not effective for organics		
• Hydrogen sulfide gas may be produced by the soluble sulfide process		

Note:

ppm - parts per million

opposed to ion exchange, is typically used for the removal of organic contaminants from aqueous wastes. The removal mechanism is sorptive rather than ion exchange. Resin adsorbents, like ion exchange resins, can be tailored to enhance selectivity for removal of specific classes of compounds (i.e., low molecular weight and polar organics) and can be regenerated using methods such as solvent washing.

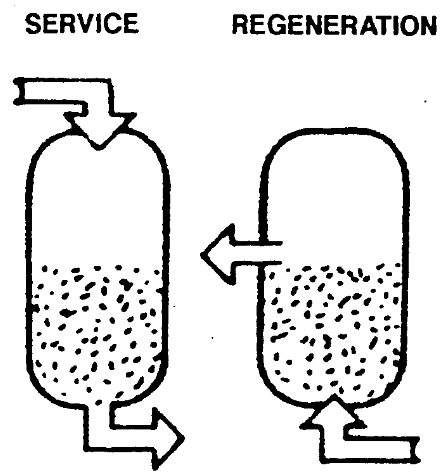
Both ion exchange and resin adsorption systems require design on a case-by-case basis. Fixed-bed concurrent, fixed-bed countercurrent, and continuous countercurrent systems are the three major operating models. The fixed-bed countercurrent system and the continuous countercurrent system in Figure 4-4 are most widely used. In the fixed-bed countercurrent system, untreated water is passed through the column from top to bottom and periodically backwashed (bottom to top) to regenerate the resin. Demineralization (removal of cations and anions) can be accomplished by using the hydrogen form of a cation exchange resin and the hydroxide form of an anion exchange resin. A combination adsorptive/demineralization system can be used for removal of organics and inorganics (USEPA, 1985a).

Continuous countercurrent systems provide simultaneous treatment, regeneration, backwash, and rinse (see Figure 4-4). This system eliminates the need to interrupt the treatment system for backwashing and allows a more complete and efficient use of the resin.

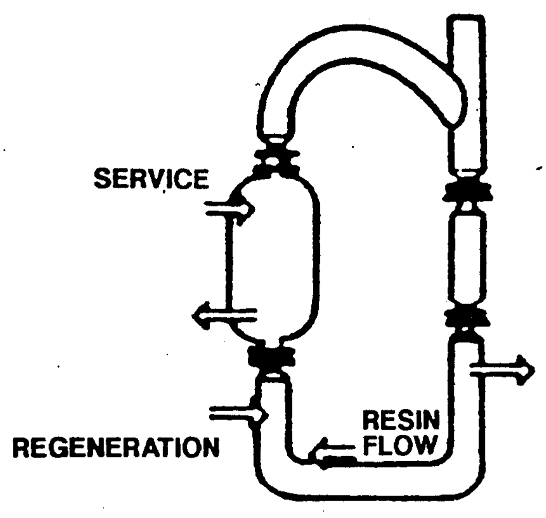
4.4.2 Technology Assessment

Reduction in Mobility, Toxicity, or Volume. Ion exchange and resin adsorption reduce the mobility of wastewater constituents by electrostatic and physical forces, respectively. In the ion exchange process, ionic contaminants in wastewater are exchanged for ions held by electrostatic forces to charged functional groups on the surface of a resin. In the resin adsorption process, contaminant molecules contacting the resin surface are held on the surface by attractive forces. Both processes remove inorganic and organic species from the wastewater stream, immobilizing them within the resin column. However, the process concentrates contaminants within the resin column, increasing toxicity of the resin.

Treatment Time. Columns are typically fed downflow at flow rates in the range of 0.25 to 2 gpm per cubic foot of resin; this is equivalent to 2 to 16 bed volumes per hour. Contact times range between 3 and 30 minutes (USEPA, 1986a). The process is discontinued when the bed is fully loaded and/or breakthrough occurs (i.e., concentration in the effluent exceeds effluent standards). Contact times may vary



COUNTERCURRENT FIXED BED



CONTINUOUS COUNTERCURRENT

SOURCE: USEPA, 1985b.

FIGURE 4-4
ION EXCHANGE SYSTEMS
REMEDIAL TECHNOLOGY HANDBOOK
BADGER ARMY AMMUNITION PLANT

depending on desired treatment standards, flow rates, and solution concentration. Potential Impact to Public Health and the Environment. If not properly contained and controlled, concentrated organics and/or inorganics in the spent resin are a potential public health and environmental hazard. The treated groundwater effluent would still contain residual concentrations of contaminants and would have to meet NPDES permit requirements to be discharged to surface water, or pretreatment requirements to be discharged to the next unit process in the treatment system. Breakthrough could result in contaminated effluent. Public health and environmental impacts could also result from improper handling and/or disposal of the regeneration solution and extracted solutes.

Secondary Waste Management Requirements. Residuals generated during ion exchange and resin adsorption include waste solutions from the regeneration process and spent resins. Regeneration of the resin bed is typically performed by backwashing the bed with basic, acidic, or salt solutions or recoverable nonaqueous solvents. Basic solutions are used for the removal of weakly acidic solutes and acidic solutions for the removal of weakly basic solutes. The waste solution will be concentrated with contaminants removed from wastewater and therefore must be either pretreated (e.g., solidified) and disposed of in a secure landfill or further treated on-site. Steam regeneration may be considered for VOCs; however, the condensed steam may then require treatment to eliminate dissolved organics (USEPA, 1986b). Spent resins can be landfilled or incinerated.

Technical Feasibility and Reliability. Ion exchange is used to remove a wide range of ionic contaminants from wastewater, including the following (USEPA, 1985a):

- All anionic or cationic metallic elements when present as soluble species.
- Inorganic anions such as halides, sulfates, nitrates, and cyanides.
- Organic acids (e.g., carboxylic, sulfonic, and some phenolics) at a pH sufficiently alkaline to cause ionization or partial ionization.
- Organic amines if solution acidity is sufficiently acidic to form the corresponding acid salt.

Sorptive resins can be effective for removing a broad range of polar and non-polar organics.

There are no specific limitations on upper contaminant concentration levels that can be treated. An upper limit for ion exchange has been estimated to be approximately 2,500 to 4,000 mg/ℓ (USEPA, 1985a). Higher concentrations result in rapid exhaustion of the resin and consequently high regeneration costs. Although the efficiency of resin adsorption increases with concentration, the upper limit of 8 percent for resin adsorption is suggested to maintain cycle time and regeneration frequency within reasonable limits (USEPA, 1986b).

Wastewater characteristics that may inhibit either process include the following:

- High suspended solids (greater than 50 mg/ℓ) (USEPA, 1985a)
- High dissolved solids (greater than 5,000 mg/ℓ) (Patterson, 1985)
- The presence of CYN (except ferrocyanides), ferrous iron, strong oxidants, MN, silica, and organic complexes (humic and fulvic acids) because these may permanently foul or degrade the resin

<u>Demonstrated Performance</u>. Ion exchange is a well-established technology for removal of dilute solutions of metals, other cations, and anions. Traditional uses of ion exchange include removal of selected dissolved metals as polishing or recovery steps, nitrate removal for drinking water purification, and decreasing total dissolved solids (TDS) of influents. Ion exchange is frequently used in drinking water treatment to soften the water by removing ions (e.g., CA and MN).

Industrial applications of ion exchange are primarily recovery operations for dilute solutions of metals, where the value of the recovered metals makes the process economical. Metals can be removed as ions in solution or as complexes. Organic compounds are generally removed using resin adsorption rather than ion exchange.

Hazardous waste treatment applications (i.e., treatment of contaminated groundwater) are not as established as traditional and industrial applications. Groundwater treatment using ion exchange exclusively is often difficult due to the complexity of the wastestream. Therefore, it may be more applicable as a pretreatment or polishing step or for treatment of a contaminant not easily treated by other means. For example, nitrate removal from groundwater using ion exchange has been demonstrated at full-scale (USEPA, 1987).

Use of adsorptive resins for treatment of organics is relatively new and often not used full-scale due to expense. Data demonstrating the use of resins are limited and reliability under various conditions is not well known. Adsorptive resins are, however, being used for color removal from dyestuffs and paper mill wastestreams, for phenol removal, and for polishing high purity waters.

Table 4-5 summarizes effluent concentrations and percent removals achieved by ion exchange (inorganics) and resin adsorption (organics). The data were collected in 1982 from various literature sources (USEPA, 1982).

Availability of Technology and Related Services. Ion exchange and resin adsorption systems are commercially available from a number of manufacturers and vendors. A wide variety of resins is available for use in designing a treatment system. Manufacturers provide charts characterizing the resins they produce, including recommendations for typical applications. Generally, the manufacturer can suggest an appropriate resin based on wastewater characteristics.

Monitoring and Maintenance Requirements. Effluent sampling is required to determine when resin bed exhaustion has occurred. For two columns in series, samples are taken from the influent entering the final column. When the first column reaches breakthrough, it is taken off-line for regeneration while the remaining column remains in service. Exchange columns can either be operated manually or automatically. Manual operation is often suggested for hazardous waste sites due to the diversity of the wastestreams. In addition, manual operation allows the operator to monitor the system and decide when to stop the service cycle and begin the backwash cycle. This requires the use of a skilled operator.

Treatability Studies. Because ion exchange is a demonstrated technology, treatability investigations are not recommended for the inorganic wastestream at BAAP. However, various constituents that could be present in the groundwater may preclude use of an ion exchange system (i.e., high TDS, MN, and FE). Therefore, the technology may require treatability investigations to evaluate the effects of these constituents on resins. Treatability investigations are recommended for adsorptive resin systems. Data are limited regarding the demonstrated performance of resins for the removal of organic contaminants in groundwater.

Capital Cost. Approximate capital costs for various sizes of ion exchange units are as follows (USEPA, 1985a):

TABLE 4-5
IONIC EXCHANGE AND RESIN ADSORPTION OVERALL REMOVAL DATA SUMMARY FOR INORGANIC AND ORGANIC CONTAMINANTS

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	EFFLUENT CONC (mg/l)					PERCENT REMOVAL				
	NO. DATA POINTS	MEAN	MEDIAN	MIN	MAX	NO. DATA POINTS	MEAN	MEDIAN	MIN	MAX
Arsenic	19	1.65	0.60	0	8.0	19	87.1	96.5	21	100
Cadmium	17	0.019	0.0003	0.0001	0.1	17	96.8	99.9+	75+	99.9+
Chromium	12	0.36	0.05	0.01	1.8	11	96.7	99.5	88	99.9
Copper	3	1.8	2.0	0.5	3.0	4	96.5	97.0	93.0	99+
Cyanide	4	15	0.15	0.1	60	5	86.6	93.3	50	100
Lead	2	0.03	0.03	0.01	0.05	2	99.85	99.85	98.8	99.9
Mercury	5	0.0005	0.0001	0	0.002	5	99.9+	99.9+	99.9+	100
Silver	6	3.5	3.7	0.01	50	7	93.7	95.0	90.0	100
Zinc	8	2.2	0.45	0	1000	9	97.7	99.0	90.0	100
Phenol	4	11.5	10.5	0.1	25	4	98.5	99.7	95	99.9+
Color (APHA)	7	997	125	21	3035	7	81	78.5	66	95
Phenol	6	5	1.0	0.6	25	6	98.6	99.4	95	99.9+
Chlorinated Pesticides	3	0.1	0.1	<0.00005	0.1	3	98.0	99.4	95	99.5
COD	5	500	187	7.5	1120	5	65	64	51	83
BOD	2	137	137	117	157	2	50	50	50	50
TOC	3	96	3.0	0.85	285	3	73	80	50	90
2-4 Dichlorophenol	2	2.0	1.1	ND	5	3	99.2	98	99.6	100
Trichlorophenol	2	6	6	0.0013	12	2	89	89	79	99.5
Trichloroguaiacol	2	22.5	22.5	0.015	45	2	87	87	78	95.8
Trichloroethylene	2	<0.0001	<0.0001	<0.0001	<0.0001	2	96.1	96.1	94.8	97.5
Tetrachloroethylene	3	<0.0001	<0.0001	ND	<0.0001	3	97.5+	97.5+	95+	100
Trichloroethane	2	0.13	0.13	<0.0001	0.04	3	94	94	87	99.9+
Dichloroethane	2	<0.0001	<0.0001	<0.0001	0.0001	2	98.6	98.6	97.4	99.8
Humates	1	5	5	5	5	1	75	75	75	75
Permanganate	1	6	6	6	6	1	53	53	53	53
Dihydroabietic Acid	1	0.011	0.011	0.011	0.011	1	88	88	88	88
Heptadecanoic Acid	1	0.02	0.02	0.02	0.02	1	52	52	52	52
p-Nitrophenol	1	7	7	7	7	1	99.4	99.4	99.4	99.4
Bisphenol A	1	64	64	64	64	1	24.9	24.9	24.9	24.9
Fulvic Acid	1	24	24	24	24	1	76	76	76	76
TNT	1	1.0	1.0	1.0	1.0	1	99	99	99	99
Paranitrophenol	1	3	3	3	3	1	99.9+	99.9+	99.9+	99.9+
Chlorobenzene	1	0	0	0	0	1	100	100	100	100
p-Dichlorobenzene	1	6.2	6.2	6.2	6.2	1	83	83	83	83
Nitro Benzene	1	0	0	0	0	1	100	100	100	100
Dinitro Benzene	1	0.7	0.7	0.7	0.7	1	91	91	91	91
Carbon Tetrachloride	1	ND	ND	ND	ND	1	100	100	100	100
Dissolved Organics	1	1.5	1.5	1.5	1.5	1	29	29	29	29

Source: USEPA 1982

Notes:

ND = Not Detected
CONC = Concentration
mg/L = Milligrams per liter
COD = Chemical Oxygen Demand
BOD = Biochemical Oxygen Demand
TOC = Total Organic Carbon
TNT = Trinitrotoluene

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Flow Rate (gpm)	Capital Cost ($)
50	95,000
195	131,300
305	152,300
438	174,000
597	203,700

Capital costs for construction of the units assume fabricated steel contact vessels with baked phenolic linings, a resin depth of 6 feet, housing for the columns, and all piping and backwash facilities.

Operation and Maintenance Costs. O&M costs for ion exchange units include electricity for backwashing (after 150-bed volumes) and periodic repair and replacement costs. Because regenerant chemicals vary depending on the types and concentrations of specific contaminants to be removed, costs for the chemicals have not been included in the O&M cost listed as follows (USEPA, 1985a):

Flow Rate (gpm)	Annual Cost ($)
50	16,400
195	24,000
305	27,400
438	31,200
597	35,600

Cost Sensitivity. Capital costs depend on the number, types, and concentration of contaminants in the wastestream, and process flow rates. Capital costs will increase as flow rates and concentrations increase because it is necessary to size equipment accordingly. Costs also will vary depending on the number and types of contaminants because specific resins (and individual columns for each different resin) will be necessary for different applications. Capital costs also increase in cold-weather climates where buried piping, heating, and housing units are required.

O&M costs are highly dependent on the resin usage rate and type of regeneration solution required.

Summary. The major advantages and disadvantages of ion exchange and resin adsorption are summarized in Table 4-6.

TABLE 4-6
EVALUATION CRITERIA SUMMARY: ION EXCHANGE AND RESIN ADSORPTION

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Treatment by ion exchange and resin adsorption involves contacting contaminated groundwater with resins by flow through a reactor or series of packed bed reactors. Ion exchange is the process of exchanging selected ionic contaminants with ions held by the ionic exchange resin. The sorptive resins adsorb organics by a surface attraction phenomenon.

EFFECTIVENESS	IMPLEMENTABILITY	COST
Advantages	Advantages	Advantages
• Immobilizes contaminants within resin	• High technical feasibility and demonstrated performance for ion exchange	• O&M costs potentially low (compared to carbon adsorption) due to low regeneration costs and extended life of resins
• Continued pumping and treatment reduces volume of contaminated groundwater plume	• Self-contained and mobile units available	
• Quick start-up times: typically less than 1 week	• Several experienced vendors are available to provide equipment and services	
• Ionic exchange effectively treats many metals and inorganics		
• Use of several exchange columns can provide considerable flexibility		
• Regeneration of resin is simple and nondestructive		
Disadvantages	Disadvantages	Disadvantages
• Does not destroy contaminants, only concentrates them	• Effluent sampling required to assess breakthrough	• High capital costs
• Waste regeneration solution is considerably more toxic than influent water; special disposal or destruction is required	• Pretreatment may be required for suspended solids, total dissolved solids, manganese, oil, or grease	
• Cannot remove all contaminants; residuals will remain in effluent stream	• May require treatability investigations	
• Documentation for groundwater applications limited	• Low demonstrated performance of resin adsorption	
• Resins are susceptible to fouling		

Note:

O&M - operation and maintenance

4.4.3 Potential Site Applicability

Sites where ion exchange and/or resin adsorption are potentially applicable due to concentration of metals (e.g., CD, CR, and PB), inorganics (e.g., NIT and SO4), and organics (e.g., 24DNT, 26DNT, TRCLE, and CCL4) detected above Wisconsin Enforcement Standards include the following:

- Propellant Burning Ground
- Deterrent Burning Ground
- Existing Landfill

Ion exchange may also be a potential pretreatment option to remove metals (e.g., iron) from wastewater to prevent fouling of the primary treatment system (i.e., air strippers, carbon adsorption beds, UV/oxidation system).

4.5 ULTRAVIOLET/OXIDATION

This subsection describes the types of UV/oxidation.

4.5.1 Description

UV/oxidation treatment involves the simultaneous application of UV radiation and other oxidants to degrade low concentrations of aqueous organics. Ozone, hydrogen peroxide, and UV light have been documented as oxidants. Cost considerations and ozone mass transfer factors limit the use of UV/ozonation to applications involving one percent or lower contaminant concentration levels. Hydrogen peroxide is a highly water soluble oxidant and it's use in UV/hydrogen peroxide treatment is limited only by cost considerations. Typically, it is also used to treat low concentrations of aqueous organics. Because degradation by UV/oxidation occurs nonselectively, it is generally used only for aqueous wastes containing a high proportion of hazardous constituents versus nonhazardous oxidizable compounds, thus focusing treatment on contaminants of concern and minimizing oxidant usage (USEPA, 1986b).

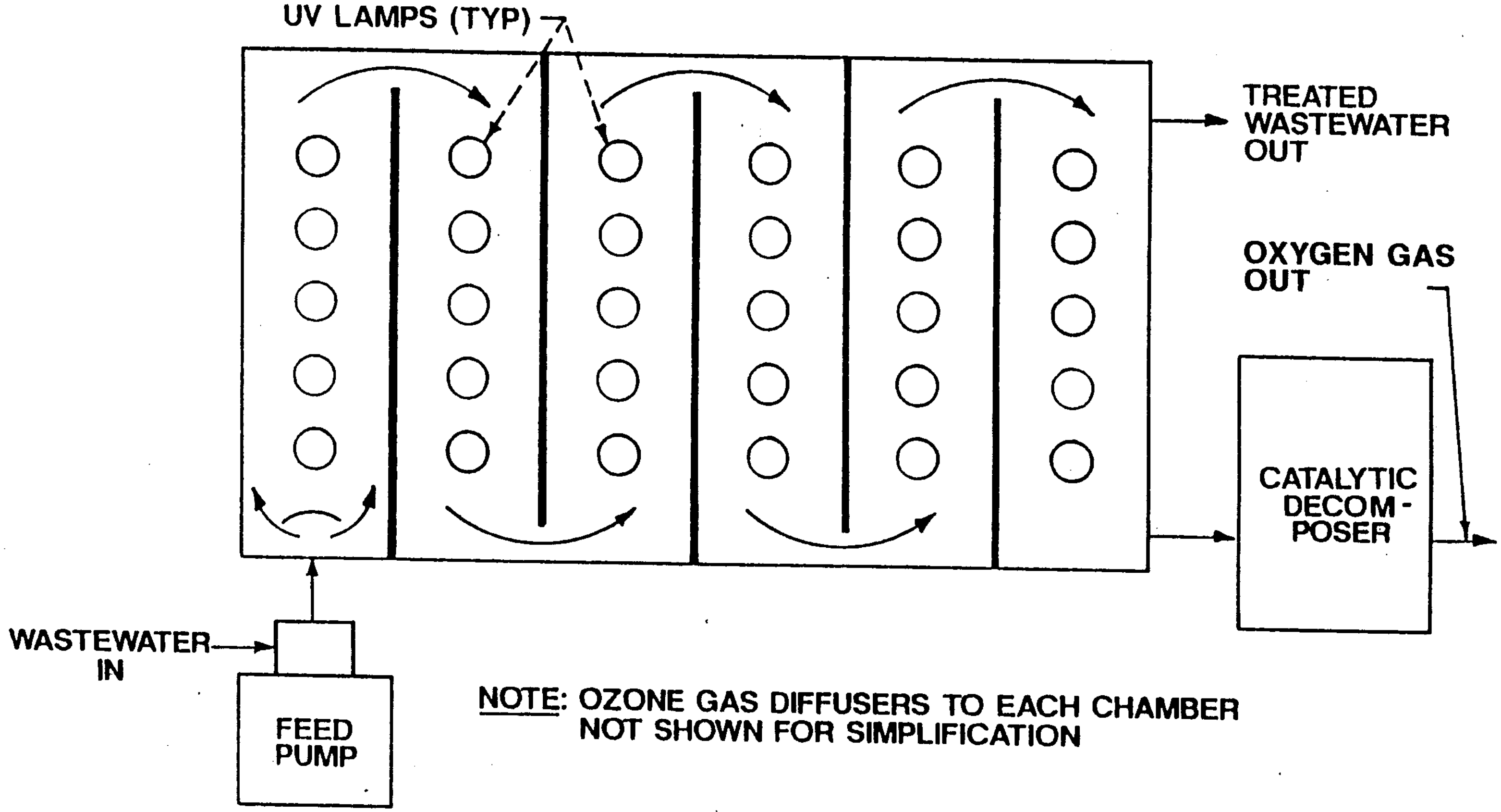
Both ozone and hydrogen peroxide are highly reactive oxidants. When added to an aqueous solution and exposed to UV light, hydroxyl radicals are produced that have a higher oxidation potential than the oxidants themselves. Recent developments in UV/oxidation technology include the addition of catalysts to improve the efficiency

of hydroxyl radical generation (Reed, 1990). In addition to facilitating the formation of hydroxyl radicals, UV light is capable of degrading many organic compounds by photolysis. The combined effects of either hydrogen peroxide or ozone and UV light is an increased oxidation rate many times faster than any of the three processes applied alone. There are, however, some chemicals that are relatively resistant to UV/oxidation treatment. Although treatable, ketones may require longer reaction times to achieve complete oxidation.

Commercialized UV/ozone treatment systems are available for drinking water, wastewater, and groundwater treatment applications. A typical system consists of four basic components: an air compressor, an ozone generator, UV lamps, and a reactor tank. The compressor supplies air as feed for ozone production. A heatless absorption dryer dries the feed air prior to introduction into the ozone generator, where ozone is produced at a concentration of 2 percent by weight. Oxygen can also be used for ozone generation, producing increased ozone concentrations (i.e., 3 to 5 percent by weight). The wastestream influent to the system is mixed with ozone as it travels through the reactor tank, which is separated into a series of chambers (Figure 4-5). Ozone is metered into each chamber from the bottom via the use of metering valves on the ozone feed stream. The chambers provide contact space for ozone and the wastestream in the presence of UV light. Flow patterns and configurations are designed to maximize exposure of the ozone-bearing wastestream to the UV light. The system emits UV radiation at less than 400-nanometers (nm) wavelength (typically 254 nm) with mercury vapor lamps. The lamps are enclosed in quartz sheets and spaced along the length of each reactor chamber (see Figure 4-5). Exhaust gas leaving the chambers is routed to a catalytic decomposer to convert residual ozone back to oxygen.

Controllable operational parameters for the UV/ozone system include ozone generator output, gas flow to the reaction vessel, treatment water flow rate, and UV light intensity. Each parameter may be varied to achieve the desired destruction efficiency of the water being treated.

The principal component of the UV/hydrogen peroxide system is a stainless steel oxidation chamber containing horizontally mounted UV lamps. The chamber is baffled to facilitate UV radiation contact with the influent stream. Figure 4-6 depicts the oxidation chamber and other components of the UV/hydrogen peroxide system. A process water pump feeds influent water through an in-line static mixer and into a distributor mounted inside and at the bottom of the oxidation chamber. Hydrogen peroxide is injected ahead of the static mixer. The mixture of influent water and



NOTE: OZONE GAS DIFFUSERS TO EACH CHAMBER NOT SHOWN FOR SIMPLIFICATION

FIGURE 4-5
UV/OZONE REACTION VESSEL
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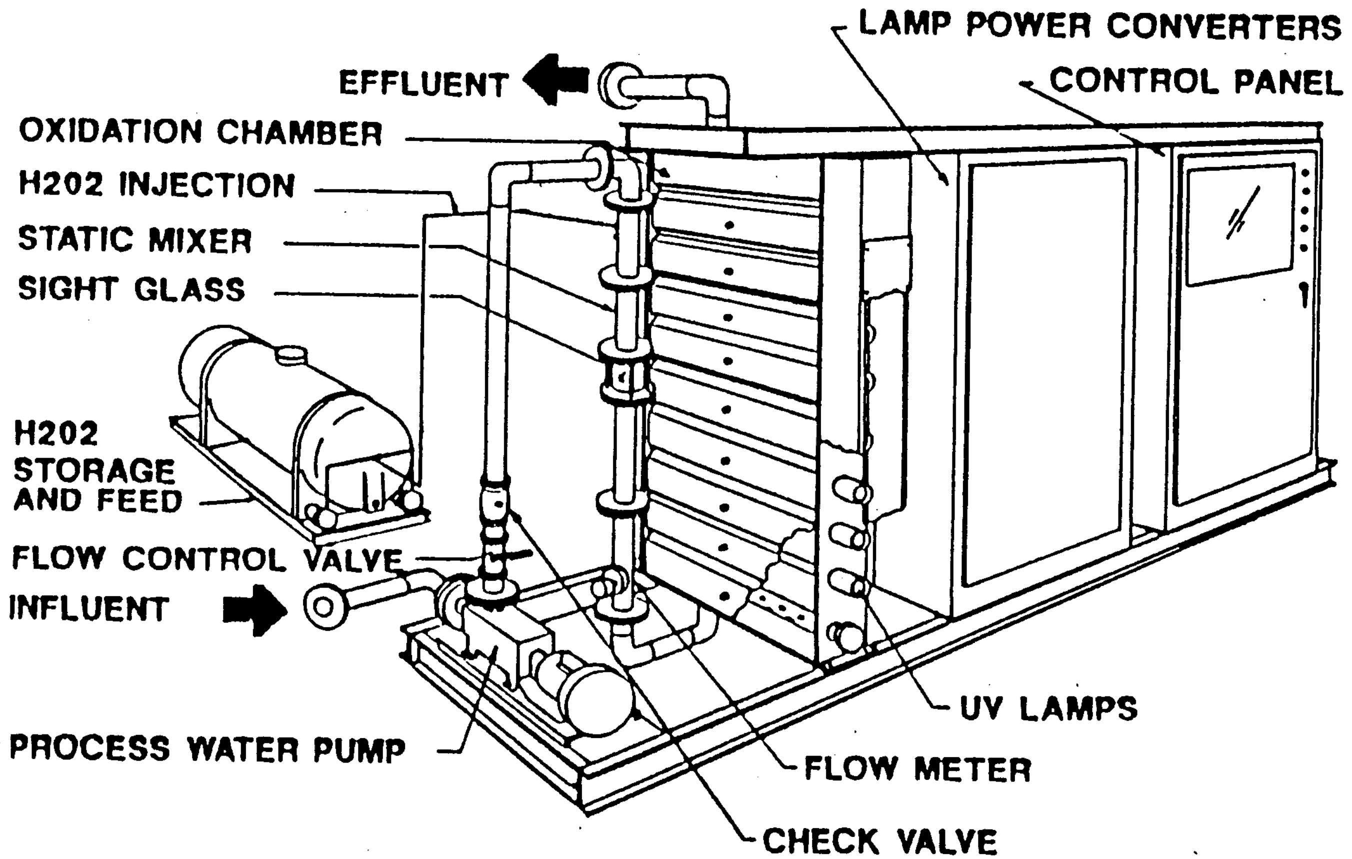

SOURCE: HAGER, JUNE 1988.

FIGURE 4-6
UV/HYDROGEN PEROXIDE PROCESS
REMEDIAL TECHNOLOGY HANDBOOK
BADGER ARMY AMMUNITION PLANT

6298-09

ABB Environmental Services, Inc.

hydrogen peroxide flows upward past the UV lamps in a turbulent flow pattern. The system emits UV radiation at less than 400-nm wavelength (typically 254 nm) with high-intensity mercury vapor lamps. The lamps are enclosed in quartz sheets and spaced along the length of the oxidation chamber (see Figure 4-6). Treated water exits from the top of the oxidation chamber.

UV/hydrogen peroxide treatment depends on process variables related to the type and concentration of organic contaminants present in the influent stream. Process variables include UV and hydrogen peroxide doses, pH, temperature, mixing, and catalysts. These variables are controlled by both initial equipment design and operational procedures.

Depending on concentrations of carbonates/bicarbonates, metals and suspended solids in the wastestream, all of which can reduce the efficiency of the UV/oxidation treatment process, a pretreatment system may be required ahead of the system.

4.5.2 Technology Assessment

Reduction in Mobility, Toxicity, and Volume. UV/oxidation would reduce the volume and toxicity of contaminated groundwater through oxidation of organic contaminants into innocuous species (i.e., carbon dioxide and water) or partial oxidation into nontoxic intermediates. Destruction efficiencies as demonstrated by pilot-scale tests for both UV/ozone and UV/hydrogen peroxide range from 70 to more than 99 percent, depending on the particular organic compound. Metals and other inorganics are oxidized to salts. The process is clean, producing no air emissions (i.e., it is nonventing) and little sludge.

The process would reduce the volume of contaminated groundwater by an amount equivalent to the process flow rate and could be discharged to receiving streams, the on-base treatment plant, or reinjected back into the aquifer after treatment. Discharges would be regulated and permitted according to federal and state standards.

Treatment Time. Approximately one year of testing, design, and construction is required prior to full-scale treatment. Testing includes both bench- and pilot-scale testing. Bench-scale testing can be completed in less than six weeks. Pilot-scale testing involves three to four weeks of mobilization time, including travel; at least one week of field testing; two months for sample analysis and analytical data validation; and one month for generation of a report. After completion of the pilot-

scale study report, design (e.g., equipment sizing, building requirements, and power connections) and construction activities generally require four to six months.

UV/oxidation systems can be sized to accommodate any flow rate. Large systems may require multiple parallel units. Full-scale units can be operated for several years.

Potential Impact to Public Health and the Environment. Ozone is harmful to public health and the environment. However, because generated ozone is contained within the treatment system, no exposure threat to public health or the environment exists from properly managed systems. Ozone in the off-gas can be converted to oxygen by a catalytic decomposer, eliminating any release of ozone to the atmosphere.

Hydrogen peroxide decomposes spontaneously. If accidentally spilled on-site, it can be diluted with water and quickly degrades to oxygen gas and water. Although hydrogen peroxide can be a dermal hazard to treatment facility workers, no adverse public health or environmental impacts would be expected, if adequate workplace protective measures are in place.

Secondary Waste Management Requirements. When treating wastewater, UV/oxidation does not in of itself produce secondary wastestreams. However, the reactor tank requires routine cleanings to remove the accumulation of metal salts and/or scale from the quartz sheets that separate the UV lights from the wastestream. Attenuation of UV light by fouled quartz sheets can severely reduce the efficiency of the UV/oxidation system. Chemicals that may be used during reactor tank cleaning could produce a sludge requiring further handling and/or treatment. Additionally, the wastewater influent may require pretreatment due to high concentrations of carbonates/bicarbonates, metals and/or suspended solids. Further handling and/or treatment may be required for sludge generated from pretreatment.

Technical Feasibility and Reliability. As demonstrated through pilot-scale testing and full-scale operations, UV/oxidation treatment is applicable to organics including VOCs (e.g., TRCLE, tetrachloroethylene [TCLEE], 111TCEA, CHCL3, and CCL4), PCBs, methylene chloride, phenolics, benzene derivatives, pesticides, CYN, tetrahydrofuran, explosives, alcohols (high molecular weight), vinyl chloride, and many others. Removal efficiencies would be determined during bench- and pilot-scale studies performed on site-specific wastestreams.

Carbonates/bicarbonates, metals, and suspended solids interfere with performance reliability. Dissolved metals and carbonates/bicarbonates will oxidize and precipitate within the reaction vessel. These precipitates, as well as suspended solids, reduce penetration of the UV light either as a result of settling onto the quartz sheets that separate the lights from the wastestream or by remaining in suspension. The overall effect on the UV/oxidation system is to diminish the ability of the system to oxidize organic compounds. Therefore, pretreatment (e.g., precipitation and filtration) may be necessary for some wastestreams. However, a recent development in UV/oxidation technology has produced a reactor tank with automated mechanical light cleaning mechanisms that allow for more efficient system operation with fewer cleanings (Reed, 1990). The long-term reliability of a full-scale UV/ozone system can be affected by the inherently sensitive nature of the ozone generator. Because of a high operating voltage, close tolerances, and cooling requirements, the ozone generator is prone to failure without strict adherence to operating parameters and performance of regular overhauls.

Demonstrated Performance. The UV/oxidation process is a demonstrated technology, substantiated both by research and pilot-scale studies. Full-scale systems have proven effective within the wood-preserving, semiconductor, electronics, explosives, and chemical manufacturing industries. This technology is well-suited for groundwater applications because of its relatively fast rate of reaction for oxidizing low concentrations of organics (i.e., less than 1 percent), such as those typical of contaminated aquifers. A UV/hydrogen peroxide unit operating in Newark, New Jersey, treated 10-mg/ℓ influent concentrations of VOCs (i.e., trans-1,2-dichloroethene and toluene [MEC6H5]) to less than 1-μg/ℓ effluent concentrations. A UV/hydrogen peroxide system at a site in New York demonstrated 99 percent removal efficiencies for influent concentrations ranging from 3.7 to 11.5 mg/ℓ of TRCLE, vinyl chloride, cis-1,2-dichloroethene, TRCLE, MEC6H5, and TCLEE.

Availability of Technology and Related Services. Vendors are available to perform bench- and pilot-scale tests; design, supply, and install equipment; and provide technical assistance for UV/ozone and UV/hydrogen peroxide systems.

Monitoring and Maintenance Requirements. Effluent samples are to be taken on a regular basis to satisfy NPDES requirements; sampling periods are typically weekly or biweekly once system operations are past the start-up phase. Maintenance for both UV/ozone and UV/hydrogen peroxide systems include daily checks to record all meter readings and monthly cleaning of the quartz sheets covering UV lights (depending on whether automatic light cleaning mechanisms are used).

Additional UV/ozone system maintenance includes annual overhaul of the ozone generator. The UV/ozone system monitors UV light intensity, ozone generation, and residual ozone in the effluent stream. UV bulbs typically require replacement on an annual basis. The UV/hydrogen peroxide system contains fewer moving parts (e.g., no ozone generator) and therefore requires minimal maintenance. The high-intensity UV bulbs used in the UV/hydrogen peroxide system are typically replaced two to three times per year.

Treatability Studies. Prior to full-scale design, bench- and pilot-scale testing is required. Bench-scale testing will determine the potential of UV/oxidation to treat BAAP groundwater and achieve effluent limitations (i.e., NPDES permit requirements), and will provide approximate costs that would be incurred for full-scale treatment. Pilot-scale studies are used to optimize UV light intensity, oxidant supply, and residence times to meet effluent limitations.

Capital Costs. Approximate capital costs associated with UV/oxidation are as follows:

• Bench-scale Tests	\$3,500 - \$15,000
• Pilot-scale Tests	\$5,000 - \$30,000
• Equipment	
3-GPM Unit	\$40,000
40-GPM Unit	\$90,000
80-GPM Unit	\$120,000
120-GPM Unit	\$160,000
• Permanent Building	\$100,000
• Power Hook-Up	variable
• Installation/Start-up	\$5,000

Additional capital costs include a 10 percent fee for engineering services and 5 to 10 percent for permitting.

Operation and Maintenance Costs. Typical O&M costs, including electrical usage and chemicals (i.e., hydrogen peroxide) range from \$0.50 to \$7.00 per 1,000 gallons for both UV/ozone and UV/hydrogen peroxide systems. Annual sampling and analysis costs can range from \$10,000 to \$25,000, depending on sampling requirements set by permits or regulatory authorities.

Cost Sensitivity. Variances in capital equipment costs are a function of the contaminants being treated and the number of orders of magnitude of removal required to meet treatment target levels. These variables will determine the size and cost of the UV/oxidation system. Power tie-ins will be more expensive for isolated sites than for sites close to existing power sources. The concentration of nonhazardous oxidizable compounds in the wastestream influences operating costs. Higher concentrations of nonhazardous oxidizable compounds result in increased demand for oxidants and UV light, which in turn increases operating costs. Pretreatment, if necessary, will increase costs depending on the material, initial concentration, removal required, and volume of sludge generated.

Summary. The major advantages and disadvantages of UV/oxidation are summarized in Table 4-7.

4.5.3 Potential Site Applicability

The potential for using UV/oxidation groundwater treatment technology at BAAP depends on several factors including the type and concentration of contaminants in groundwater, the concentrations of nonhazardous oxidizable compounds in groundwater, and treatment target levels. A test program (i.e., bench- and pilot-scale testing) would be performed prior to final design of the system. UV/oxidation groundwater treatment technology is potentially applicable to the Propellant Burning Ground.

4.6 CONTAINMENT/SLURRY WALL

This subsection discusses containment using a slurry wall.

4.6.1 Description

Slurry walls are subsurface barriers that reduce groundwater flow in unconsolidated earth materials. The walls are constructed by excavating a vertical trench that is kept full with a bentonite slurry to hydraulically shore the trench and prevent collapse. The two most common material mixes used to backfill slurry trenches are a soil-bentonite slurry and a cement-bentonite slurry. Both vertical and horizontal placement options are available and are illustrated in Figure 4-7. Slurry walls can be vertically "keyed-in" or hung, and placed horizontally upgradient (relative to the

TABLE 4-7
EVALUATION CRITERIA SUMMARY: UV/OXIDATION

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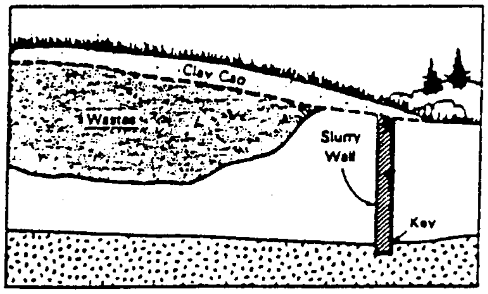
UV/oxidation units employ a simultaneous application of UV light and either ozone or hydrogen peroxide within a baffled reactor vessel to oxidize organics to carbon dioxide and water or nontoxic intermediates. The combined effects of either hydrogen peroxide or ozone and UV light is greater than the sum of any of the three components applied separately.

EFFECTIVENESS	IMPLEMENTABILITY	COST
Advantages	Advantages	Advantages
• Permanent destruction of organics into carbon dioxide and water, or nontoxic intermediates. Destruction efficiencies range from 70 to >99%	• Demonstrated technology	• Pilot-scale study costs typically $20,000 to $25,000 for vendor services
• Produces no air emissions and little sludge	• Systems can accommodate a variety of flow rates	• Capital costs comparable to other water treatment processes for organics
• Reduces overall volume of contaminated groundwater by an amount equivalent to the process flow rate	• Pilot studies have shown processes to be applicable to all priority list pollutants	• Operation and maintenance costs are typically less than $1.00 per 1,000 gallons for groundwater applications with microgram per liter contamination
• Operation poses no increased public health or environmental risks	• Minimal design procedures consist primarily of several days of pilot-scale studies, followed by a few weeks of specification and design work	
• Effluent may be discharged to receiving waters, groundwater, or local POTW	• Experienced vendors available to perform bench- and/or pilot-scale tests, provide equipment, and related services	
Disadvantages	Disadvantages	Disadvantages
• High suspended solids, carbonates/biocarbonates, or metals (e.g., iron, manganese) require pretreatment to maintain overall effectiveness	• May require pretreatment for suspended solids, carbonate/biocarbonates, and/or metals	• Annual sampling costs estimated at $10,000 to $20,000 per year, depending on NPDES requirements
• Lower removal rates for some organics (e.g., ketones)	• Ozone generator is susceptible to failure without rigorous attention to operating parameters and maintenance	
	• When using UV/hydrogen peroxide, equipment must be shut off between intermittent flows because high-intensity lamps may boil off water	

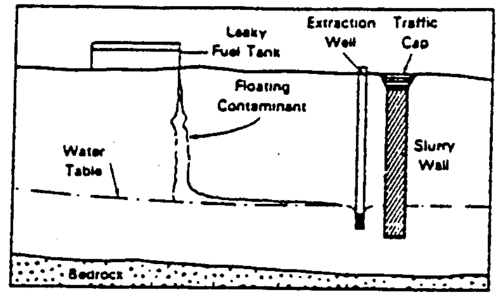
Notes:

NPDES - National Pollutant Discharge Elimination System
POTW - publicly owned treatment works

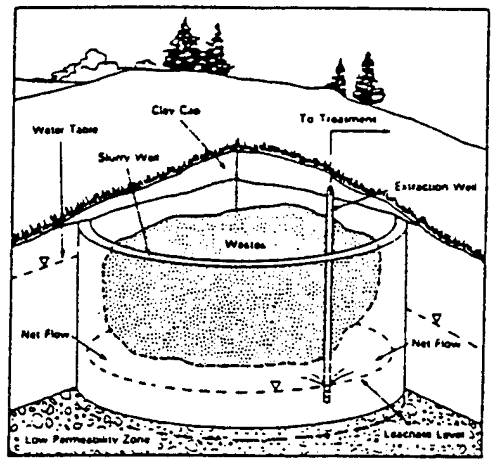
Keyed-in Slurry Wall



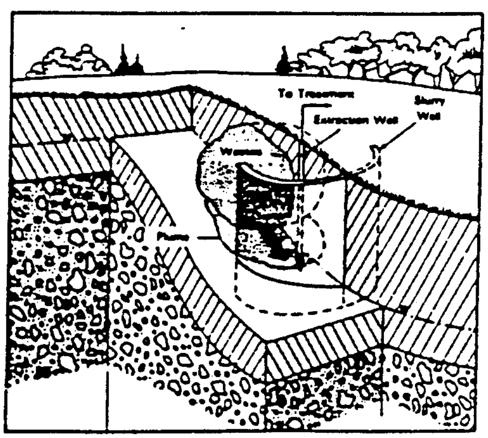
Hanging Slurry Wall



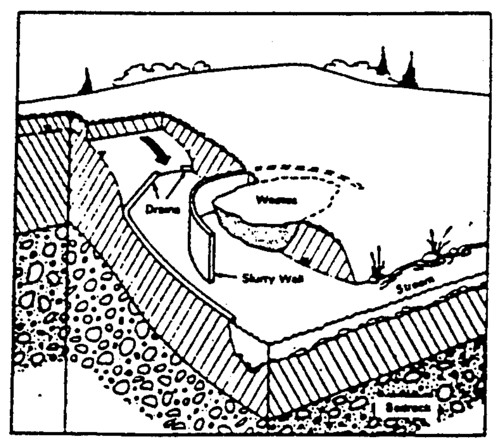
Cutaway Cross Section of Circumferential Wall Placement



Cutaway Cross Section of Downgradient Placement



Cutaway Cross Section of Upgradient Placement with Drain



SOURCE: USEPA,1985b.

FIGURE 4-7
EXAMPLES OF SLURRY WALL PLACEMENT OPTIONS
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direction of groundwater flow), downgradient, or completely around the area of concern.

Keyed-in slurry walls (see Figure 4-7) are constructed in a trench excavated into a low-permeability confining layer (i.e., clay or bedrock). This layer forms the bottom of the site and is essential for adequate containment. Hanging slurry walls are not tied into a confining layer but are extended into the water table and act as a barrier to nonaqueous contaminants (e.g., oils and fuels).

Of the horizontal slurry wall placement options, circumferential installations are the most common. Circumferential installations reduce the amount of uncontaminated groundwater entering the site and therefore reduce the volume of leachate generated. In addition, installation of an infiltration barrier (i.e., low-permeability clay or synthetic cover) and a leachate collection system in conjunction with the slurry wall can maintain the hydraulic gradient and prevent leachate from escaping.

Placement of a slurry wall upgradient of the groundwater plume can be used to divert uncontaminated groundwater around a contaminant source in high gradient situations. This method will not eliminate generation of leachate but could slow its generation by stagnating groundwater. Placement of a slurry wall downgradient of the groundwater plume can be used to intercept nonaqueous contaminants.

4.6.2 Technology Assessment

Reduction in Mobility, Toxicity, or Volume. Containment of a groundwater plume by installation of a slurry wall does not treat contaminants. The toxicity, potential mobility, and volume of contaminants remain the same; however, they may be in a more stable, contained environment with lower exposure potential.

The effect of contaminants on the short- and long-term integrity of the slurry wall is difficult to quantify. A number of chemical compounds (i.e., strong acids and bases, sulfates, and other highly ionic substances) can have a detrimental effect on slurry walls. In addition, data indicate that organic contaminants in groundwater can cause desiccation and cracking in soil-bentonite mixtures and therefore result in permeability increases of several orders of magnitude (USEPA, 1985b). However, additional data indicate that if organics are at or near solubility limits in aqueous solution, no appreciable increase in permeability occurs (USEPA, 1985b). Compatibility testing between the constituents and the slurry wall mix prior to installation is still highly recommended.

The presence of a low-permeability confining layer beneath the site is also a consideration in limiting migration of contaminants. The layer must have a low enough permeability so that vertical migration is prevented and have sufficient thickness (i.e., 2 to 3 feet) to allow adequate depth for key-in of the wall (USEPA, 1985b). The depth of the confining layer also will determine the type of excavation equipment required and affect the actual cost of the wall.

Treatment Time. The time required to install a slurry wall depends heavily on the length, depth, and type of mix used to backfill the excavation. Assuming a soil-bentonite mix and a 25-foot depth, installation has been estimated at approximately 4,500 square feet per day.

Potential Impact to Public Health and the Environment. A slurry wall reduces the potential long-term impact on public health and the environment if the contaminant is successfully contained. Major routes of exposure during the slurry wall installation are from direct contact and particulate and vapor inhalation. Direct contact exposure can be minimized by restricting access to the site and the use of protective equipment by workers. Continuous air quality monitoring is required to determine if risks from vapor inhalation exist.

Secondary Waste Management Requirements. Contaminated material excavated during construction of the slurry wall is the only secondary waste generated. If native soil is not appropriate for use in the bentonite mix or if the cement-bentonite slurry is used to backfill the trench, all contaminated soil must be disposed of in an approved landfill or receive treatment.

Technical Feasibility and Reliability. Containment of contaminated groundwater with slurry walls is technically feasible. Slurry walls, especially soil-bentonite slurry walls, have been used successfully for decades to control groundwater in conjunction with dam projects (USEPA, 1985b). However, the ability of slurry walls to maintain long-term integrity and prevent permeation by various contaminants is questionable. Compatibility between contaminants and backfill material has been demonstrated in the laboratory through permeation tests. However, long-term effectiveness is still under evaluation. As stated previously, the two most common backfill mixes are a soil-bentonite slurry and cement-bentonite slurry. Soil-bentonite slurry walls are less expensive than cement-bentonite walls, have a wider range of chemical compatibilities, and can be designed to achieve lower permeabilities (i.e., $1x10^{-8}$ centimeters per second [cm/sec] versus $1x10^{-6}$ cm/sec) (USEPA, 1985b). Cement-bentonite walls have a lower compressibility (i.e., more strength) than soil-bentonite

walls, require a smaller work area, and do not require a level site. Because soil-bentonite walls do not set into a semirigid solid (as do cement-bentonite walls), these types of walls are not appropriate for sites with varied topography.

Demonstrated Performance. In recent years, slurry walls have been used at a variety of hazardous waste sites to control contaminant migration in groundwater. In 1982, the soil-bentonite slurry wall technique was implemented and completed at a site in California. A 3,400-foot-long, 100-foot-deep slurry trench cutoff wall was installed around the site and permeabilities of $1x10^{-7}$ cm/sec or less were achieved consistently throughout the project. The cement-bentonite technique has also been implemented at several sites. A wall 7,000 feet long and 25 feet deep with a maximum permeability of $1x10^{-6}$ cm/sec was installed and completed at another site in California. To prevent infiltration, the site was capped with a 40-mil, high-density polyethylene liner. Groundwater monitoring wells were installed along the wall to demonstrate the continued effectiveness of the system.

Availability of Technology and Related Services. Equipment and materials required to construct a slurry wall are readily available. In addition, a number of vendors offer the required services.

Maintenance and Monitoring Requirements. Quality control is an important aspect of slurry wall construction. Areas of quality control that are particularly important include slurry quality, trench dimension and continuity, and cutoff wall composition and placement. Visual monitoring of the construction as well as testing of the slurry material to determine whether it meets specifications should be conducted throughout the project.

After construction, no operation is required, and maintenance of the wall is minimal. Maintenance of ancillary measures (i.e., caps and leachate collection systems) must be conducted periodically. Monitoring groundwater levels inside and outside slurry walls is typically performed to determine that design head levels are not exceeded. Groundwater quality is also monitored to check integrity of the wall.

Treatability Investigations. Although containment of groundwater with a slurry wall is a demonstrated technology, treatability investigations are recommended due to the difficulty in quantifying the effects chemical contaminants may have on slurry wall permeability. Because the wastestream at BAAP consists of a number of constituents at varying concentrations, compatibility testing is recommended.

Capital Costs. Costs for slurry walls are typically expressed in costs per unit area of wall (i.e., dollars per square foot). Therefore, total costs are determined by the depth and length; width is determined by the type of excavation equipment used. Costs include drilling, materials, and equipment.

Cost estimates for slurry walls range between $4 and $15 per vertical square foot of slurry wall. Cement-bentonite mixes are typically more expensive than soil-bentonite mixes and are in the middle to upper range of the estimate.

Operation and Maintenance Costs. Groundwater monitoring costs to detect migration of contaminants are the only substantial maintenance costs associated with slurry walls. As stated previously, no operation is required and maintenance of the wall primarily consists of periodic inspections. Monitoring costs, which include sampling and analytical costs, may range between $5,000 and $50,000 per year, depending on sampling frequency (i.e., quarterly, semiannually, or annually), sampling parameters, and the number of wells sampled.

Cost Sensitivity. The cost of installing a slurry wall depends on job complexities (e.g., utilities and site restoration), construction methods, wall type, and backfill characteristics. Costs increase with depth and ease of excavation and may increase substantially if it is necessary to import soil from off-site resources for soil-bentonite mixes.

Summary. The major advantages and disadvantages of containment/slurry walls are summarized in Table 4-8.

4.6.3 Potential Site Applicability

Sites where containment may be a potential means of remediation include those sites where groundwater is contaminated with organic constituents or metals. Groundwater contamination due to NIT encompasses areas sufficiently large to make installation of a slurry wall cost prohibitive.

Sites where organic and/or inorganic contaminant plumes may be contained using a slurry wall include the following:

- Propellant Burning Ground
- Deterrent Burning Ground
- Existing Landfill

TABLE 4-8
EVALUATION CRITERIA SUMMARY: CONTAINMENT/SLURRY WALL

REMEDIAL TECHNOLOGY HANDBOOK
BADGER ARMY AMMUNITION PLANT

Slurry walls are subsurface barriers that act to contain or divert contaminated groundwater. A vertical trench is backfilled with a chosen material mix, typically either soil-bentonite or cement-bentonite.

EFFECTIVENESS	IMPLEMENTABILITY	COST
<u>Advantages</u>	<u>Advantages</u>	<u>Advantages</u>
• May limit migration of chemicals present in groundwater • Groundwater containment may reduce the potential for off-site impact • Site would be monitored for chemical migration	• Vendors are available to install slurry walls	• Costs for installation of a slurry wall is estimated to be between $4 and $15 per square foot
<u>Disadvantages</u>	<u>Disadvantages</u>	<u>Disadvantages</u>
• Containment would not reduce the toxicity, potential mobility, or volume of chemicals in groundwater • Compounds present may have adverse affects on the hydraulic barriers • Unproven long-term effectiveness	• A slurry wall would have an approximately 250 foot depth from ground surface to bedrock at BAAP • Existing utilities and buildings may have to be relocated in order to install a slurry wall at BAAP • Treatability investigations may be necessary to determine contaminant/backfill material compatibility	• Future remediation costs may be high if this alternative proves ineffective

Note:

BAAP - Badger Army Ammunition Plant

4.7 IN-SITU BIOREMEDIATION

This subsection describes the in-situ bioremediation process. Two in-situ bioremediation methods have shown potential for the treatment of aquifers contaminated with hazardous wastes; aerobic and anaerobic biodegradation. Aerobic biodegradation relies on oxygen-requiring microbial processes. Anaerobic biodegradation relies on one of two different processes: (1) sulfate- or nitrate-requiring microbial processes, or (2) interactive fermentative/methanogenic processes, which are carried out by what is referred to as a methanogenic consortium (USEPA, 1985b). Anaerobic biodegradation using a methanogenic consortium has been tested for its potential to treat chlorinated organics. Test results indicate that injection of methane into an anaerobic aquifer containing a methanogenic consortium will facilitate degradation of halogenated aliphatics (e.g., CCL4 and TRCLE). Aerobic biodegradation may not be capable of treating halogenated aliphatics but is it capable of treating many other organics, including petroleum hydrocarbons, aromatics (e.g., benzene), and halogenated aromatics (e.g., pentachlorophenol) (USEPA, 1985b). Additionally, aerobic biodegradation is the most developed and feasible of the two methods. Consequently, aerobic biodegradation is the method that is described and addressed in the following evaluation. However, many of the following concerns and considerations that apply to aerobic biodegradation also apply to anaerobic biodegradation.

4.7.1 Description

In-situ bioremediation is a process in which nutrients and oxygen are injected into a contaminated aquifer in order to increase the capacity of the indigenous subsurface microbial population to degrade organic contaminants in the aquifer. In-situ bioremediation can be used for total remediation of an aquifer, to intercept a groundwater contaminant plume and isolate it from off-site areas, or to remediate the aquifer underlying the source area and prevent further contamination of the aquifer.

Metered amounts of oxygen and nutrients are delivered to extracted groundwater in a water-amendment system and then pumped to injection wells strategically located within the groundwater contaminant plume. Biodegradation of organic contaminants in the groundwater is stimulated as the oxygen and nutrients are sorbed to aquifer sediments in the immediate vicinity of each injection site. As the contaminants are biodegraded, oxygen consumption rates near the injection well screens will decline,

and zones of elevated dissolved oxygen (oxic zones) will form in those regions of the aquifer. As injection continues, the oxic zones will expand downgradient, stimulating contaminant biodegradation at increasing distances from the injection sites. Theoretically, oxygen will travel downgradient faster than organic contaminants and will overtake the contaminants after the oxygen demand in the vicinity of the injection sites is satisfied (Piotrowski, M.R., J.R. Doyle, and J.W. Carraway, 1992). The expanding oxic zones produced by each injection site will also eventually overlap, creating a zone of enhanced biological activity across the width of the contaminant plume. Figure 4-8 is a conceptual depiction of an in-situ bioremediation system.

The selection of an oxygen source is primarily dependent upon the concentration of contaminants in the aquifer. When low concentrations (i.e., parts-per-billion) of organics are present in the aquifer, an oxygen generator may be used to deliver dissolved oxygen to injected water. For applications where higher concentrations (i.e., parts-per-million) of organics require remediation, hydrogen peroxide may be selected as the oxygen source (Piotrowski, M.R., J.R. Doyle, and J.W. Carraway, 1992).

Hydrogen peroxide can supply much higher concentrations of oxygen than can be achieved by dissolving pure oxygen in water. Although hydrogen peroxide is cytotoxic at high concentrations, studies indicate it can be added to groundwater in concentrations up to 100 mg/L without adverse effects, assuming proper formulation and control (Heyse, E., S.C. James, and R. Wetzel, 1986).

The selection of nutrients for injection into the aquifer is dependent upon an analysis of the existing conditions in the aquifer. The analysis will determine if nutrients that contribute to the growth of the microbial population are either not present or are present in growth-limiting concentrations. A mixture of nutrients that will enhance microbial growth is then formulated for injection into the groundwater. To prevent precipitation of some of the nutrients in the injection wells, chelating agents may have to be added to the mixture (Heyse, E., S.C. James, and R. Wetzel, 1986).

4.7.2 Technology Assessment

Reduction in Mobility, Toxicity, and Volume. Subsurface microbes reduce the mobility, toxicity, and volume of biodegradable organic contaminants by metabolic or co-metabolic processes. Complete biodegradation will produce biomass, carbon dioxide, and water.

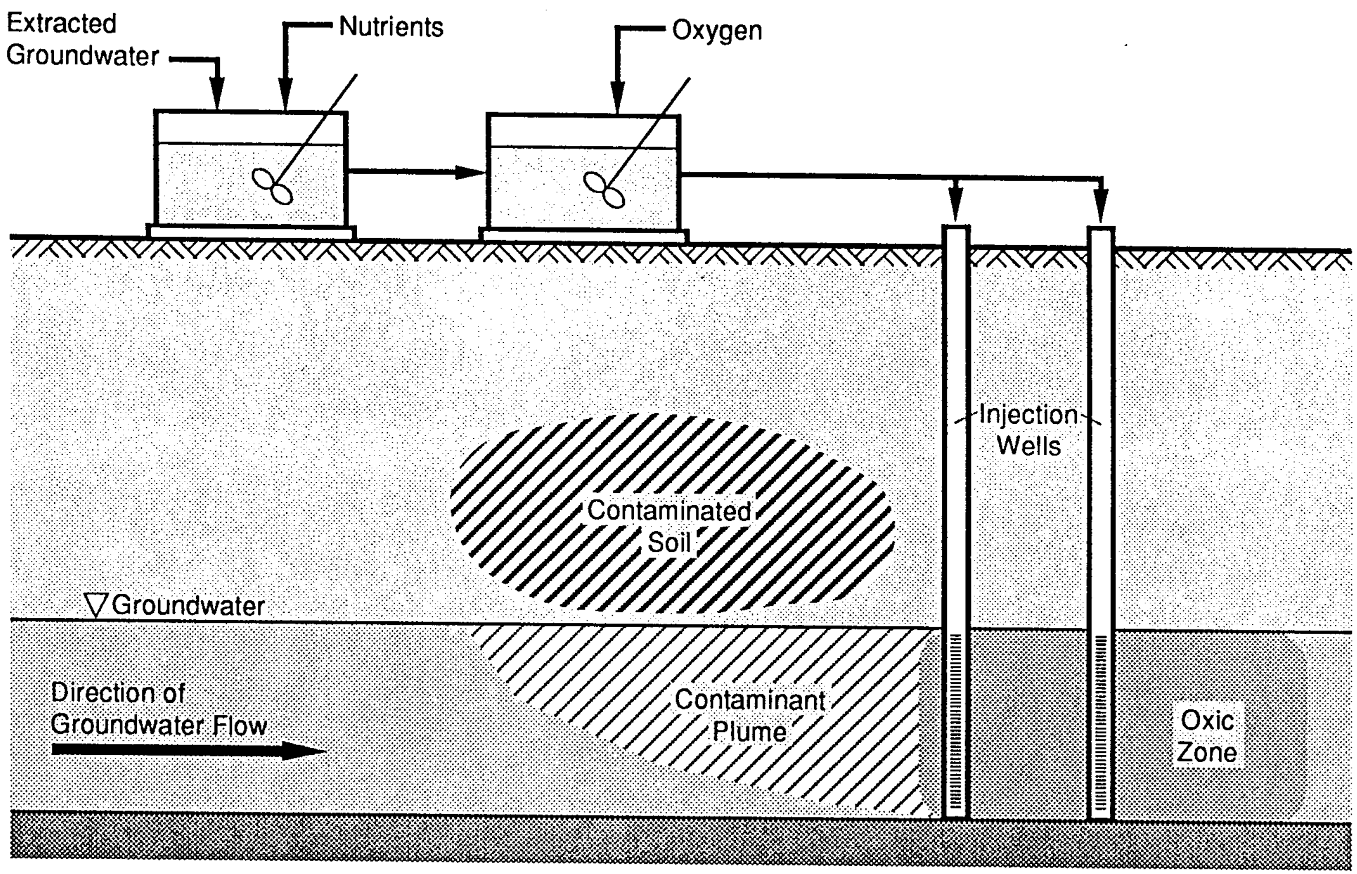

FIGURE 4-8
IN-SITU BIOREMEDIATION LAYOUT
REMEDIAL TECHNOLOGY HANDBOOK
BADGER ARMY AMMUNITION PLAN
ABB Environmental Services, Inc.

9208040D

Treatment Time. The time required to treat groundwater contaminants depends on the potential of the contaminants for biodegradation, the biodegradation rate, the volume of contaminated groundwater, and the hydrogeologic characteristics (e.g., permeability) of the aquifer. A full-scale demonstration of a single injection site (approximately 57 gpm of a hydrogen peroxide solution) at a Superfund site in Libby, Montana produced an area of elevated dissolved oxygen concentration greater than 400 feet in width and 1,000 feet long after approximately six months of operation. A corresponding decrease in contaminant concentrations is assumed for that area (Piotrowski, M.R., J.R. Doyle, and J.W. Carraway, 1992).

Potential Impact to Public Health and the Environment. The water-amendment and injection systems can be designed and operated so that there is minimal potential for spills or vapor releases which would result in exposure of the public or the environment to groundwater contaminants. No secondary wastestreams are generated during in-situ biodegradation and the products of complete biodegradation (i.e., biomass, carbon dioxide, and water) are harmless.

Hydrogen peroxide may present a dermal hazard to site workers. However, hydrogen peroxide decomposes spontaneously and if accidentally spilled on site, it can be diluted with water to facilitate degradation into oxygen gas and water. No adverse public health or environmental impacts would be expected from the use of hydrogen peroxide, if adequate workplace protective measures are in place.

Secondary Waste Management Requirements. No secondary wastestreams would be produced by this technology.

Technical Feasibility and Reliability. This technology has been shown to be a feasible technology for full-scale remediation of aquifers contaminated with biodegradable organic contaminants, particularly hydrocarbons. Test results indicate that it has the potential for treating halogenated organics. Halogenated organic contaminants are typically more resistant to biodegradation than other classes of organics and the feasibility of treating halogenated organics would have to be proven on a case-by-case basis. The technology is in the preliminary stages of development and its reliability in meeting specified performance goals has not been determined.

Demonstrated Performance. A pilot-scale study was conducted at a Superfund site in Libby, Montana to determine injection system effectiveness for supplying dissolved oxygen (delivered as a dilute solution of hydrogen peroxide) to the aquifer underlying the site and to evaluate the effect of oxygen injection on dissolved contaminant

concentrations in the treatment area. Aquifer contaminants included creosote and pentachlorophenol. The study, which lasted for more than a year, found that the formation of an oxic zone in the contaminated aquifer coincided with significant reductions in dissolved contaminant concentrations (from thousands of ug/L to about 1 ug/L total dissolved contamination). As was previously stated, a full-scale demonstration at the same site resulted in the creation of an oxic zone approximately 400 feet by 1,000 feet in area. In-situ bioremediation is one of the selected technologies that will be used for groundwater remediation at that site (Piotrowski, M.R., J.R. Doyle, and J.W. Carraway, 1992).

Although in-situ bioremediation has been selected for groundwater remediation at hazardous waste sites, a full-scale remediation has not been completed and little information is available on its ability to effectively treat different types of contaminants under different types of hydrogeologic conditions. The only full-scale use of in-situ bioremediation has been at gasoline spill sites, where it has proven to be an effective technology.

Availability of Technology and Related Services. Equipment and services for in-situ bioremediation are readily available. The groundwater extraction and injection wells could be installed by drilling contractors. The water-amendment and associated piping systems could be constructed by local contractors. The primary components of the water-amendment system (i.e., mixing tanks and metering pumps) are off-the-shelf items. However, an experienced vendor would be required for design of a complete system because placement of injection wells and specification of oxygen and nutrient requirements are critical to the effectiveness of a system. ABB-ES has considerable experience in the design and testing of bioremediation systems.

Monitoring and Maintenance Requirements. Groundwater monitoring is required during remediation to ensure that the specified levels of dissolved oxygen and nutrients are present in the aquifer. Operation of the water-amendment system can be adjusted to compensate for changing levels of oxygen and nutrients. Analysis for target contaminants would also be conducted during groundwater monitoring to verify attainment of performance goals.

Treatability Studies. Analysis of the existing conditions in the aquifer and treatability studies are required prior to selection of this technology. Analysis of existing conditions would determine if a sustainable population of microbes, potentially capable of degrading contaminants, is present in the aquifer and if there are any growth-limiting factors (i.e., temperature, dissolved oxygen, pH, and nutrients). The

analysis would also evaluate the hydrogeologic characteristics of the aquifer that would influence the transport of injected oxygen and nutrients.

If existing conditions indicate that the aquifer is a candidate for in-situ bioremediation, then bench-scale treatability studies would be conducted to determine if the indigenous subsurface microbes are capable of biodegrading aquifer contaminants. The appropriate concentrations of dissolved oxygen and nutrients for optimum microbe growth would also be determined at this time.

The successful outcome of bench-scale treatability studies would lead to pilot-scale studies. The purpose of the pilot-scale studies would be to evaluate the effect of oxygen and nutrient injection on contaminant concentrations in the groundwater and to observe the distribution of the oxic zone. The placement of injection wells in the aquifer would be dependent on the outcome of the pilot-scale studies and is critical to the design of the injection system. Installation and operation of too many injection sites is costly and wasteful; too few may not be able to create an adequate oxic zone.

Capital Costs. In-situ bioremediation has not been developed to the point where accurate capital cost estimates are possible. Direct capital costs are primarily influenced by the number of injection wells required for a site. Indirect capital costs are primarily influenced by the scope of the hydrogeological and treatability studies.

Operation and Maintenance Costs. O&M of in-situ bioremediation includes costs associated with utilities, labor, chemicals, nutrients, oxygen source (i.e., hydrogen peroxide), monitoring, and administrative support. Purchasing chemicals, nutrients, and hydrogen peroxide in bulk would reduce O&M costs considerably.

Cost Sensitivity. The costs of in-situ bioremediation are sensitive to site hydrogeology, extent of contamination, types and concentrations of contaminants, and the volume of groundwater and soil requiring treatment.

Summary. The major advantages and disadvantages of in-situ bioremediation are summarized in Table 4-9.

4.7.3 Potential Site Applicability

In-situ bioremediation can be used to treat aquifers contaminated with certain organic compounds. An extensive program of hydrogeological and treatability studies

TABLE 4-9
EVALUATION CRITERIA SUMMARY: IN-SITU BIOREMEDIATION

REMEDIAL TECHNOLOGY HANDBOOK
BADGER ARMY AMMUNITION PLANT

Nutrients and oxygen are injected into an aquifer contaminated with organic compounds. The formation of zones of elevated dissolved oxygen in the aquifer will facilitate aerobic biodegradation of the organic compounds.

EFFECTIVENESS	IMPLEMENTABILITY	COST
Advantages	Advantages	Advantages
• Reduces mobility, toxicity, and volume of organics other than halogenated aliphatics	• Feasible at sites with adaptable and sustainable microbial population	• Reduced treatment time could result in reduced costs when compared to other technologies
• Complete biodegradation will produce biomass, carbon dioxide, and water	• Technology has been demonstrated for full-scale remediation of gasoline spill sites	• Nutrients and chemicals can be obtained at low cost
• Treatment time is not dependent on desorption of contaminants from aquifer matrix	• Pilot-scale studies have demonstrated potential for remediation of aquifers contaminated with halogenated aromatics (i.e., PCP)	
• Minimal Potential for spills or vapor releases which could harm public health/environment	• Nutrient and oxygen sources (i.e., oxygen generator or hydrogen peroxide) readily available	
• No secondary wastestreams		
Disadvantages	Disadvantages	Disadvantages
• May not be capable of treating halogenated aliphatics (e.g., TRCLE and CCL4)	• Not demonstrated for full-scale remediation of aquifer contaminated with chlorinated organics	• Costs for aquifer investigations and treatability studies could be significant
	• Extensive aquifer investigations and treatability studies required	
	• Extensive monitoring of nutrients and oxygen in groundwater required during remediation	

Notes:

TRCLE = Trichloroethylene
CCL4 = Carbon Tetrachloride
PCP = Pentachlorophenol

would be required prior to design and construction. In-situ bioremediation is potentially applicable to the Propellant Burning Ground.

ARC	Atlantic Research Corporation
ARAR	Applicable or Relevant and Appropriate Requirement
ATP	Anaerobic Thermal Process
BAAP	Badger Army Ammunition Plant
B.E.S.T.	Basic Extractive Sludge Treatment
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
cm/sec	centimeters per second
cy	cubic yards
cy/day	cubic yards per day
EP	Extraction Procedure
FS	Feasibility Study
GAC	granular activated carbon
gpm	gallons per minute
IRM	Interim Remedial Measures
ISP	insoluble sulfide precipitation
Land Ban	RCRA Subchapter I, Part 268 Land Disposal Restrictions
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
nm	nanometers
NPDES	National Pollutant Discharge Elimination System
O&M	operation and maintenance
PAH	polynuclear aromatic hydrocarbon
PCB	polychlorinated biphenyl
PCE	perchloroethylene
ppm	parts per million
RCC	Resource Conservation Company

GLOSSARY OF ACRONYMS AND ABBREVIATIONS

RCRA	Resource Conservation and Recovery Act
RTH	Remedial Technology Handbook
SITE	Superfund Innovative Technology Evaluation
SSP	soluble sulfide precipitation
SVE	In situ Vacuum Extraction
SVOC	semivolatile organic compound
S/S	stabilization/solidification
TCLP	toxicity characteristics leaching procedure
TEA	triethylamine
TDS	total dissolved solids
USEPA	U.S. Environmental Protection Agency
UV	ultraviolet
VOC	volatile organic compound
Weston	Roy F. Weston, Inc.
$\mu g/L$	micrograms per liter

ANAPNE	acenaphthene
ANAPYL	acenaphthylene
ACET	acetone
ALKN	alkane
AL	aluminum
NH4	ammonia
ANTRC	anthracene
SB	antimony
AS	arsenic
BA	barium
C6H6	benzene
BAANTR	benzo(a)anthracene
BAPYR	benzo(a)pyrene
BBFANT	benzo(b)fluoranthene
BGHIPY	benzo(g,h,i)perylene
BENZOA	benzoic acid
BKFANT	benzo(k)fluoranthene
BTA	benzothiazole
BZALC	benzyl alcohol
BE	beryllium
B2EHP	bis(2-ethylhexyl)phthalate
BRCLM	bromochloromethane
CHBR3	bromoform
CH3BR	bromomethane
BBZP	butylbenzylphthalate
CD	cadmium
CA	calcium
CS2	carbon disulfide
CCL4	carbon tetrachloride
CL	chloride
CLC6H5	chlorobenzene
C2H5CL	chloroethane
CHCL3	chloroform
CH3CL	chloromethane
CR	chromium
CHRY	chrysene
C12DCE	cis-1,2-dichloroethene

C13DCP	cis-1,3-dichloropropene
CU	copper
CYN	cyanide
CYHX	cyclohexane
RDX	cyclonite
CPO	cyclopentanone
HMX	cyclotetramethylenetetranitramine
DBAHA	dibenzo(a,h)anthracene
DBRCLM	dibromochloromethane
CL2BZ	dichlorobenzene
DEP	diethylphthalate
DMP	dimethylphthalate
DNBP	di-n-butyl phthalate
DNB	dinitrobenzene
DNP	dinitrophenol
DNT	dinitrotoluene
DNOP	di-n-octylphthalate
DPA	diphenylamine
ETC6H5	ethylbenzene
FANT	fluoranthene
FLRENE	fluorine
F	fluoride
C7A	heptanoic acid
CL6BZ	hexachlorobenzene
CL6ET	hexachloroethane
HXMTSX	hexamethylcyclotrisiloxane
HXADOE	hexanedioic acid, dioctyl ester
ICDPYR	indeno(1,2,3-cd)pyrene
FE	iron
PB	lead
MG	magnesium
MN	manganese

HG	mercury
CH2CL2	methylene chloride
MIPK	methylisopropyl ketone
N	nitrogen
NAP	naphthalene
NI	nickel
NO3	nitrate
NO2	nitrite
NIT	nitrite/nitrate-nonspecific
NANIL	nitroaniline
NB	nitrobenzene
NC	nitrocellulose
NG	nitroglycerine
NDNPA	nitrosodi-n-propylamine
NT	nitrotoluene
NNDNPA	n-nitrosodi-n-propylamine
NNDPA	n-nitrosodiphenylamine
o-CL2BZ	o-dichlorobenzene
p-CL2BZ	p-dichlorobenzene
PCP	pentachlorophenol
PHANTR	phenanthrene
PHENOL	phenol
PHENLC	phenolics
PHTHL	phthalates
K	potassium
PYR	pyrene
SE	selenium
AG	silver
NA	sodium
STYR	styrene
SO4	sulfate
TCLEE	tetrachloroethylene
THF	tetrahydrofuran
SN	tin
MEC6H5	toluene

T12DCE	trans-1,2-dichloroethene
T13DCP	trans-1,3-dichloropropene
TRCLE	trichloroethylene
CCL3F	trichlorofluoromethane
TNT	trinitrotoluene
V	vanadium
XYLEN	xylene
ZN	zinc
1C4L	1-butanol
11DCLE	1,1-dichloroethane
11DCE	1,1-dichloroethylene
111TCE	1,1,1-trichloroethane
112TCE	1,1,2-trichloroethane
TCLEA	1,1,2,2-tetrachloroethane
12DCLE	1,2-dichloroethane
12DCLP	1,2-dichloropropane
12DMB	1,2-dimethylbenzene/o-xylene
12DPH	1,2-diphenylhydrazine
12EPCH	1,2-epoxycyclohexene
13DCLB	1,3-dichlorobenzene
13DCPE	1,3-dichloropropene
14DCLB	1,4-dichlorobenzene
MEK	2-butanone
2BUXEL	2-butoxyethanol
2E1HXL	2-ethyl-1-hexanol
2MNAP	2-methylnaphthalene
2NT	2-nitrotoluene
2BEETO	2-(2-m-butoxyethoxy)ethanol
24DNT	2,4-dinitrotoluene
246TNT	2,4,6-trinitrotoluene
26DNT	2,6-dinitrotoluene
34DNT	3,4-dinitrotoluene
35DNT	3,4-dinitrotoluene
TM2HXO	5-methyl-2-hexanone

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IDENTIFICATION AND SCREENING OF REMEDIAL ACTION TECHNOLOGIES

TABLE A-1
IDENTIFICATION OF REMEDIAL ACTION TECHNOLOGIES

BADGER ARMY AMMUNITION PLANT
BARABOO, WISCONSIN

SOIL/SEDIMENT

RESPONSE CATEGORY/ CORRECTIVE ACTION TECHNOLOGY	DESCRIPTION OF TECHNOLOGY	COMMENTS
No Action		
None	No action taken to reduce exposure. May include an environmental monitoring program.	May be implemented if site contaminants do not present a significant threat to human health or the environment.
Minimal Action		
Fencing/Signs	Restrict site access with fencing; post warning signs.	Readily implementable.
Institutional Controls	Initiate zoning or deed restrictions to prohibit public use of site.	Implementable. Public use is currently restricted since BAAP is manned military facility.
Environmental Monitoring	Periodic sampling to identify increasing or decreasing risks.	Implementable.
Containment		
Capping	Place low permeability material (e.g., clay, asphalt, synthetic membrane) over area of concern to reduce dermal contact risks and precipitation.	A cap would reduce direct contact exposure to contaminated soils and reduce leachate generation.
Removal/Treatment		
On-site Incineration	Organics are thermally destroyed as soil is passed through a combustion chamber at high temperature.	Demonstrated effectiveness for destruction of halogenated and nonhalogenated semivolatile organics. Not effective for metals. Off-gases require collection/treatment.
Off-site Incineration	Excavate contaminated soils/sediments and transport to off-site facility for thermal destruction of organics.	Facilities are on-line, but transportation distances and capacity must be considered.
Vitrification Thermal Treatment	High temperature is used to reduce organic compounds to carbon monoxide, hydrogen, and carbon. Inorganic contaminants become entrained in glass and siliceous metals.	Potential effectiveness for halogenated and nonhalogenated semivolatile organics and nonvolatile metals.
Anaerobic Thermal Process	High temperature in an anaerobic environment is used to desorb organic contaminants. Detoxified soil is returned to site or disposed off-site. Concentrated contaminants require additional treatment.	Demonstrated effectiveness for treatment of halogenated and nonhalogenated semivolatiles. Interference from high fines and water content.

TABLE A-1
IDENTIFICATION OF REMEDIAL ACTION TECHNOLOGIES

BADGER ARMY AMMUNITION PLANT
BARABOO, WISCONSIN
(continued)

SOIL/SEDIMENT

RESPONSE CATEGORY/ CORRECTIVE ACTION TECHNOLOGY	DESCRIPTION OF TECHNOLOGY	COMMENTS
Thermal Soil Aeration	Contaminated soils processed through a pug mill or rotary drum system. An induced airflow conveys the desorbed volatile organic air mixture through a carbon adsorption unit or combustion afterburner.	Potential effectiveness for halogenated and nonhalogenated semivolatiles; requires elevated temperatures to volatilize semivolatile organics. Not effective for metals. Off-gases require collection/treatment.
Land Treatment	Treatment involves spreading contaminated soil over large tracts of land and aiding natural physical, chemical, and biological processes to degrade, volatilize, immobilize, or transform contaminants by aerating, fertilizing, and irrigating the soil.	May increase the rate of biological decomposition for nitrocellulose.
Biodegradation/Composting	Soils are arranged in long piles 3-6 feet high, bulking agents (e.g., wood chips) are added, and the piles are periodically turned over to facilitate aerobic and anaerobic decomposition of organic constituents. Enclosed composting reactor may be required to control volatile organic emissions.	May increase the rate of biological decomposition for nitrocellulose.
Anaerobic Biological Treatment	Relatively slow treatment process where organics are reduced to methane and carbon dioxide in the absence of oxygen.	Potential effectiveness for the dechlorination of higher chlorinated organics. Metals may be toxic to organisms.
Stabilization/Solidification	Immobilize contaminants by adding a solidifying agent (e.g., polymer, cement, fly ash, lime) to excavated soils; mix; and cure to form a solid, low-permeability matrix.	Demonstrated effectiveness for treatment of metals. Treatability testing may be necessary to obtain the appropriate mix of cement and additives to effectively bind the contaminants.
Solvent Extraction	Contaminants extracted from soil using water or other solvents. Detoxified soil is returned to site or disposed off-site. Concentrated wastewater requires additional treatment.	Potential effectiveness for treatment of halogenated and nonhalogenated semivolatiles and metals. Interference results from fine solids.
<u>In situ Treatment</u>		
Vitrification	High voltage current is passed through the contaminated zone until complete meltdown of soils has occurred. The high temperatures generated during meltdown pyrolyze and eventually combust organic constituents.	Process could be used to destroy organics and immobilize inorganics contained in soil. Off-gases require collection/treatment. Not feasible in saturated soil.

TABLE A-1
IDENTIFICATION OF REMEDIAL ACTION TECHNOLOGIES

BADGER ARMY AMMUNITION PLANT
BARABOO, WISCONSIN
(continued)

SOIL/SEDIMENT

RESPONSE CATEGORY/ CORRECTIVE ACTION TECHNOLOGY	DESCRIPTION OF TECHNOLOGY	COMMENTS
Biological	Nutrients and oxygen are circulated through contaminated zones to enhance microbial decomposition of contaminants.	Nutrients could be mixed into the permeable outwash soil to enhance biodegradation.
Soil Flushing	Water is flushed through the vadose zone and leachate is collected at well points.	Water could be flushed through the permeable outwash soil and leachate removed with extraction wells. Not effective for semivolatiles detected in soil (i.e., DNTs) due to hydrophilic nature of compound.
RF Heating	Heating shallow soils with radio frequency electrodes results in vaporizing, distilling, or decomposing organics.	Treatment efficiency is reduced by utilities and buried metals that can interfere with radio frequency path.
Neutralization	Dilute acids or bases are injected into the soil to restore caustic or acidic conditions to neutral pH.	Implementable. Severe caustic or acidic conditions do not exist at any of the BAAP sites.
Vacuum Extraction	Volatiles in soil are removed by drawing air through the air spaces between the soil particles. VOC vapors extracted may require treatment (e.g., carbon adsorption or afterburner).	Requires elevated temperatures to volatilize semivolatiles detected in soil.
Steam Stripping	Steam and hot air are injected into contaminated soil to a depth of 30 feet. Evaporated contaminants are collected and treated (e.g., carbon adsorption or afterburner).	Requires elevated temperatures to volatilize semivolatiles detected in soil.
Stabilization/Solidification	Solidification reagents (e.g., polymer, cement, fly ash, lime) are injected directly into contaminated soils.	Organic solvents are not amenable to immobilization by solidifying agents. Solvents may interfere with the proper curing of the solidified matrix. Demonstrated effectiveness for treatment of volatile and nonvolatile metals.
<u>Ancillary</u>		
Screening	Remove debris (e.g., boulders or trash) from excavated soils with meshed or mechanical screens.	Required as pretreatment step for many technologies. Reduces the volume of material to be treated.
Stabilization/Solidification	Immobilize secondary waste residuals by adding a solidifying agent (e.g., polymer, cement, fly ash, lime).	Could be used for on-site or off-site treatment and disposal of treated soil or ash.

TABLE A-1
IDENTIFICATION OF REMEDIAL ACTION TECHNOLOGIES

BADGER ARMY AMMUNITION PLANT
BARABOO, WISCONSIN
(continued)

SOIL/SEDIMENT		
RESPONSE CATEGORY/ CORRECTIVE ACTION TECHNOLOGY	**DESCRIPTION OF TECHNOLOGY**	**COMMENTS**
Dewatering	Remove water from soils with a filter press or by air drying.	Increases the efficiency of certain treatment processes (e.g., incineration).
<u>Disposal</u>		
On-site Disposal	Treated soil/sediment replaced on-site.	Must comply with RCRA subtitle C, part 268 Land Disposal Restrictions and meet remediation goals.
On-site RCRA Landfill	Secure hazardous wastes in a double-lined cell with a leachate collection system.	Must comply with Land Disposal Restrictions.
Off-site RCRA Facility	Transport hazardous wastes to an off-site permitted RCRA facility.	Must comply with Land Disposal Restrictions.

TABLE A-1
IDENTIFICATION OF REMEDIAL ACTION TECHNOLOGIES

BADGER ARMY AMMUNITION PLANT
BARABOO, WISCONSIN
(continued)

GROUNDWATER/SURFACE WATER

RESPONSE CATEGORY/ CORRECTIVE ACTION TECHNOLOGY	DESCRIPTION OF TECHNOLOGY	COMMENTS
No Action		
None	No action taken to reduce exposure. May include water quality analyses to monitor contaminant migration and assess future environmental impacts.	A groundwater monitoring system has been implemented and is currently in operation at BAAP.
Minimal Action		
Institutional Controls	Implement zoning and deed restrictions to prohibit use of groundwater within and around the sites.	Groundwater is not used as a potable supply within the BAAP boundary. Groundwater restrictions may be implemented in the future.
Groundwater Monitoring	Perform water quality analyses to monitor contaminant migration and assess future environmental impacts.	A groundwater monitoring system has been implemented and is currently in operation.
Containment		
Hydraulic Subsurface Barriers	Divert overburden groundwater flow around plume areas with slurry wall.	Slurry walls could be keyed into bedrock which is approximately 250 feet below ground surface. Should be implemented with surficial cap to be effective.
Collection		
Interceptor Trench	Trenches, drains and piping used to passively collect (by gravity flow) groundwater.	Collected groundwater would be pumped, diverted, or transported to treatment unit.
Extraction Wells	Pumping wells installed to collect groundwater.	Collected groundwater would be transported to treatment unit.
Treatment		
UV/Oxidation	UV irradiation with ozone or hydrogen peroxide react to oxidize organic contaminants.	Volatile and semivolatile compounds are broken down into nonspecific byproducts.
Air Stripping	Reduce concentrations of volatile organic compounds (VOCs) through intimate contact of extracted groundwater with air. Water descends down a packed column while air is forced up the column to promote mass transfer of organics from aqueous to gaseous phase. Gaseous phase would require further treatment to meet air regulations.	Levels of certain semivolatile compounds (DNTs) cannot be reduced easily due to low volatility. Off-gases may require collection/treatment. An air stripper, proceeded by a carbon adsorption unit, is currently in operation at the Propellant Burning Ground.

TABLE A-1
IDENTIFICATION OF REMEDIAL ACTION TECHNOLOGIES

BADGER ARMY AMMUNITION PLANT
BARABOO, WISCONSIN
(continued)

GROUNDWATER/SURFACE WATER

RESPONSE CATEGORY/ CORRECTIVE ACTION TECHNOLOGY	DESCRIPTION OF TECHNOLOGY	COMMENTS
Steam Stripping	Remove volatile organic emissions through intimate contact of extracted groundwater and steam. Similar to air stripping, but steam is used to elevate temperatures and enhance removal of volatiles.	Levels of certain semivolatile compounds cannot be reduced easily due to low volatility. Off-gases may require collection/treatment.
Carbon Adsorption	Reduce concentrations of aqueous or gaseous phase organics through adsorption onto available granular activated carbon sites. May also be used as a polishing step following treatments such as air or steam stripping.	High solids in aqueous stream will "plug" carbon bed. Carbon must be replaced periodically when breakthrough occurs. A carbon adsorption unit, followed by an air stripper, is currently in operation at the Propellant Burning Ground.
Wet Air Oxidation	Destroy organic compounds in an aqueous solution by inducing oxidation and hydrolysis reactions at high temperature and pressure. Oxygen, at elevated temperatures, enhances oxidation of organic compounds to carbon dioxide and water.	Implementable for VOCs identified in BAAP groundwater (e.g., TRCLE, CCL4, and TCLEE). Not demonstrated.
Supercritical Water Oxidation	Destroys organic compounds in an aqueous solution at high temperature and pressure. Supercritical water oxidation is a high temperature and pressure version of wet air oxidation.	Implementable for volatile organic compounds identified in BAAP groundwater (e.g., TRCLE, CCL4, TCLEE, etc.). Not demonstrated.
Thin Film Evaporation	Remove contaminants from extracted groundwater by vaporizing water from contaminants. Process produces a concentrated wastestream requiring further treatment.	Process not proven for organic compounds identified at BAAP.
Reverse Osmosis	Remove contaminants from extracted groundwater using membrane processes. At high pressures, membrane allows water to pass while organics are concentrated. Process produces a concentrated wastestream requiring further treatment.	High inorganic and/or suspended solids will "clog" filter. Not proven reliable for organics with low molecular weight (<200) identified at BAAP.
Resin Adsorption	Contaminants are transferred from the dissolved state to the surface of the resin. Can be regenerated by removing the contaminants with solvent. Process produces a concentrated waste-stream requiring further treatment.	Full-scale testing has demonstrated effectiveness for VOCs and metals.

TABLE A-1
IDENTIFICATION OF REMEDIAL ACTION TECHNOLOGIES

BADGER ARMY AMMUNITION PLANT
BARABOO, WISCONSIN
(continued)

GROUNDWATER/SURFACE WATER

RESPONSE CATEGORY/ CORRECTIVE ACTION TECHNOLOGY	DESCRIPTION OF TECHNOLOGY	COMMENTS
Biological Treatment	Destroy organics through biodegradation, acclimation-degradation, or chemical conversion of organic wastes by introducing extracted groundwater to either an aerobic or anaerobic biological treatment process.	May have to supplement influent with nutrients if BOD is not high enough to support bacterial growth.
Ion Exchange	Metal ions are removed from solution by exchanging ions electrostatically attached to a solid resin material, for dissolved ions in solution. Regeneration of the exhausted resin would produce a concentrated wastestream requiring further treatment.	Effective for removal of inorganics and nitrates.
<u>In situ Treatment</u>		
In situ Biological	Introduce nutrients and oxygen or methane into the aquifer using a matrix of injection wells and water-amendment techniques.	Wells exist that may be used for injection. Oxygen is injected into the aquifer to facilitate aerobic biodegradation of organics or methane is injected into the aquifer to facilitate anaerobic biodegradation of organics.
<u>Ancillary</u>		
Aeration	Aerate the groundwater or leachate to oxidize and precipitate out inorganic iron, manganese, calcium, and magnesium.	May be required as pretreatment step to avoid fouling of main treatment system (e.g., air stripper, carbon beds).
Filtration	Remove suspended solids from the wastewater stream by forcing the water through a sand filter or cartridge-type filter.	May be required as pretreatment step to avoid fouling of main treatment system (e.g., air stripper, carbon beds).
Precipitation/Flocculation/ Sedimentation	Chemical precipitation involves the formation of a solid phase, usually particulate matter suspended in a liquid phase, containing the pollutant to be removed. Process requires close control of pH. Process generates a sludge requiring collection/treatment/disposal.	May be required as pretreatment step to avoid fouling of main treatment system (e.g., air stripper, carbon beds).
Dewatering	Remove water from sludges with filter press prior to disposal.	To reduce volume of sludges.

TABLE A-1
IDENTIFICATION OF REMEDIAL ACTION TECHNOLOGIES

BADGER ARMY AMMUNITION PLANT
BARABOO, WISCONSIN
(continued)

GROUNDWATER/SURFACE WATER

RESPONSE CATEGORY/ CORRECTIVE ACTION TECHNOLOGY	DESCRIPTION OF TECHNOLOGY	COMMENTS
Disposal/Discharge		
RCRA Landfill (off-site)	Secure treatment residue (e.g., biological treatment sludge, spent carbon) in an off-site RCRA facility.	For treatment residuals considered hazardous. Must comply with Land Disposal Restrictions.
Incineration (off-site)	Treat and dispose residue (e.g., biological treatment sludge, spent carbon) in an off-site facility.	For organic treatment residuals considered hazardous.
Groundwater Reinjection (on-site)	Reinject treated groundwater not meeting NPDES discharge limits, within the zone of groundwater contamination.	Limited to recharge/permeability rates of soils. May require special permitting.
Discharge to Surface Water	Discharge of treated groundwater, meeting NPDES discharge limits, into surrounding surface water.	Treated groundwater from the existing treatment system is discharged to the Wisconsin River.

Notes:

BAAP	-	Badger Army Ammunition Plant
BOD	-	biochemical oxygen demand
CCL4	-	carbon tetrachloride
DNT	-	dinitrotoluene
NCP	-	National Contingency Plan
NPDES	-	National Pollution Discharge Elimination System
RCRA	-	Resource Conservation and Recovery Act
RF	-	Radio frequency
TCLEE	-	tetrachloroethylene
TRCLE	-	trichloroethylene
VOC	-	volatile organic compound
UV	-	ultraviolet

TABLE A-2
SCREENING OF REMEDIAL ACTION TECHNOLOGIES

BADGER ARMY AMMUNITION PLANT
BARABOO, WISCONSIN

SOIL/SEDIMENT

RESPONSE CATEGORY/ CORRECTIVE ACTION TECHNOLOGY	SITE-LIMITING CHARACTERISTICS	WASTE-LIMITING CHARACTERISTICS	SCREENING STATUS
<u>No Action</u>			
None	None	None	Retained; may be applicable to sites where there is no significant threat to human health or the environment.
<u>Minimal Action</u>			
Fencing/Signs	None	None	Retained.
Institutional Controls	None	None	Retained.
Environmental Monitoring	Samples cannot be taken under existing structures and utilities.	None	Retained.
<u>Containment</u>			
Capping	Currently the Existing Landfill has been capped and closed in accordance with the State of Wisconsin Solid Waste Regulations. Capping may not be practical for sites where existing structures and pavement overlie source soil areas.	None	Retained.
<u>Removal/Treatment</u>			
On-site Incineration	Not easily implementable where excavation is difficult.	Rocks and debris larger than 2 inches in diameter must be screened out prior to incineration. Test burn is required to meet RCRA destruction removal efficiencies, and stack emissions. Not suitable for direct treatment of metals.	Retained; demonstrated effectiveness for organics.
Off-site Incineration	Not easily implementable where excavation is difficult.	Regulations would apply for transport of hazardous waste.	Retained for small volumes of soil.
Vitrification Thermal Treatment	Not easily implementable where excavation is difficult.	Not effective on wastes with high moisture content.	Eliminated due to high energy requirements.

TABLE A-2
SCREENING OF REMEDIAL ACTION TECHNOLOGIES

BADGER ARMY AMMUNITION PLANT
BARABOO, WISCONSIN
(continued)

SOIL/SEDIMENT

RESPONSE CATEGORY/ CORRECTIVE ACTION TECHNOLOGY	SITE-LIMITING CHARACTERISTICS	WASTE-LIMITING CHARACTERISTICS	SCREENING STATUS
Anaerobic Thermal Process	Not easily implementable where excavation is difficult.	Interference may result from high fines and water content. Rocks and debris larger than 2 inches in diameter must be screened out.	Retained for possible treatment of semivolatiles.
Thermal Soil Aeration	Not easily implementable where excavation is difficult.	Designed to treat soils containing organics with boiling points less than 800 degrees (F), less than 10 percent total organics, and less than 60 percent moisture.	Eliminated; not effective for treatment of semivolatile organics in soils and sediments.
Land Treatment	High acreage required.	Generated leachate requires collection and recycling or treatment.	Eliminated; not proven effective for treatment of hazardous organics, (e.g., DNTs). Not effective for inorganics.
Biodegradation/Composting	High acreage required for non-enclosed systems.	May require possible treatment to control volatile emissions. High levels of lead may be toxic to organisms.	Retained; has been demonstrated for treatment of nitrocellulose at BAAP.
Anaerobic Biological Treatment	Not easily implementable where excavation is difficult.	Anaerobic decomposition of organics is a slow process. Strict control of operating conditions is required.	Eliminated; not yet proven effective for treatment of hazardous organics.
Stabilization/Solidification	Not easily implementable where excavation is difficult.	High concentrations of organics may inhibit process.	Retained for possible treatment of inorganic metals in soils or sediments.
Solvent Extraction	Not easily implementable where excavation is difficult.	Treatment interference may result from fine solids. Resultant wastewater requires treatment and disposal.	Retained for possible removal/treatment of semivolatiles and inorganics.

TABLE A-2
SCREENING OF REMEDIAL ACTION TECHNOLOGIES

BADGER ARMY AMMUNITION PLANT
BARABOO, WISCONSIN
(continued)

SOIL/SEDIMENT

RESPONSE CATEGORY/ CORRECTIVE ACTION TECHNOLOGY	SITE-LIMITING CHARACTERISTICS	WASTE-LIMITING CHARACTERISTICS	SCREENING STATUS
In Situ Treatment			
Vitrification	Soils with permeabilities higher than 10^{-4} cm/sec are difficult to vitrify in the presence of flowing groundwater. Temporary surface and groundwater diversions may be required.	Buried metals (e.g., drums, tanks) may result in electrical short circuiting and reduced treatment efficiency.	Eliminated. More economical, equally effective technologies are available, such as excavation followed by solvent extraction and solidification.
Biological	Difficult to mix oxygen and nutrients into soils under existing structures.	At high concentrations, heavy metals are toxic to microorganisms.	Eliminated due to high concentration of inorganics in soils and sediments and resistance of DNTs to biodegradation. Process difficult to control in situ.
Soil Flushing	Soil permeability may restrict influx of sufficient quantities of water to effectively flush soils.	Surfactants or other additives may be required to remove compounds of low solubility.	Eliminated. Not effective for hydrophilic contaminants (DNTs) detected in soil. Produces a concentrated wastewater requiring treatment.
RF Heating	Shallow groundwater impedes heating process. Difficult to implement in areas where soils are under existing structures.	Effective to a depth of 5-10 ft. Buried metal (e.g., drums, storage tanks) interferes with radio frequency path and reduces treatment efficiency.	Eliminated. Technology would interfere with routine communications at the BAAP.
Neutralization	Soil permeability may restrict influx of sufficient quantities of water to effectively neutralize soils.	Solubility of metals may result. No significant acid or caustic contamination to warrant remediation.	Eliminated. The historical acid/caustic pits (New and Old Acid Areas) soils do not present a potential risk to public health or the environment.
Vacuum Extraction	Difficult to implement in areas where soils have a high moisture content.	Effective for removal of volatile organics; not effective for nonvolatile metals. May require off-gas treatment.	Retained for treatment of volatile organics in subsurface soils.
Stream Stripping	Difficult to implement if structures and utilities overlie source areas.	Effective for removal of volatile and less volatile organics; not effective for nonvolatile metals. Requires vapor-phase treatment.	Eliminated. Not appropriate for site contaminants.
Stabilization/Solidification	Difficult to implement if structures and utilities overlie source areas.	Effective for treatment of metals attached to soil particles.	Retained for treatment of metals in soils.

TABLE A-2
SCREENING OF REMEDIAL ACTION TECHNOLOGIES

BADGER ARMY AMMUNITION PLANT
BARABOO, WISCONSIN
(continued)

SOIL/SEDIMENT

RESPONSE CATEGORY/ CORRECTIVE ACTION TECHNOLOGY	SITE-LIMITING CHARACTERISTICS	WASTE-LIMITING CHARACTERISTICS	SCREENING STATUS
Ancillary			
Screening	None.	Saturated soils would require dewatering before screening.	Retained. Applicable as ancillary treatment for most soil technologies retained.
Stabilization/Solidification	None.	For on-site or off-site treatment of waste residuals.	Retained for immobilization of inorganics in residual.
Dewatering	None.	Soil/sediments may require dewatering depending on the type of technology used for treatment of contaminants.	Retained. Some treatment technologies require dewatering as a pretreatment step.
Disposal			
On-site Disposal	Must comply with Land Disposal Restrictions and meet remediation goals.	None.	Retained. If soil has been treated to meet Land Disposal Restrict-ions, is nonhazardous, and meets remediation goals, the soil can be backfilled on site.
On-site RCRA Landfill	Must comply with Land Disposal Restrictions.	Relatively small volume of waste to be disposed of.	Eliminated. Permits for RCRA landfills are expensive and difficult to obtain. Other disposal options are available.
Off-site RCRA Facility	Limited number of facilities already operating at maximum capacity. Must comply with Land Disposal Restrictions.	None.	Retained. For off-site disposal of treatment residuals if on-site disposal not feasible.

TABLE A-2
SCREENING OF REMEDIAL ACTION TECHNOLOGIES

BADGER ARMY AMMUNITION PLANT
BARABOO, WISCONSIN

GROUNDWATER/SURFACE WATER

RESPONSE CATEGORY/ CORRECTIVE ACTION TECHNOLOGY	SITE-LIMITING CHARACTERISTICS	WASTE-LIMITING CHARACTERISTICS	SCREENING STATUS
No Action			
None	None.	None.	Retained; may be applicable to sites where there is no significant threat to human health or the environment.
Minimal Action			
Institutional Controls	None.	None.	Retained. Administratively feasible.
Groundwater Monitoring	None.	None.	Retained. Wells installed on-site.
Containment			
Hydraulic Subsurface Barriers	Existing structures and utilities may make implementation difficult. Implementation would require placement of barrier in bedrock at a depth of approximately 250 feet.	Barrier design would require consideration of groundwater contaminants that may degrade barrier.	Retained.
Collection			
Interceptor Trench	Existing structures and underground utilities may restrict use.	None.	Eliminated due to depth of groundwater (approximately 100 feet below ground surface).
Extraction Wells	Installation of wells would require locating underground utilities.	None.	Retained.
Removal/Treatment			
UV/Oxidation	None.	Color and suspended solids must be reduced to ensure effective treatment of organics. Not effective for treatment of inorganics.	Retained for groundwater treatment.
Air Stripping	None.	Inorganics may require pretreatment to avoid scaling or fouling of the tower. Off-gas would require collection/treatment/disposal (e.g., carbon adsorption). Not effective for compounds with low volatility.	Retained for groundwater treatment. Currently implemented on site.
Steam Stripping	Energy source required for steam generation.	Inorganics would require pretreatment to avoid scaling or fouling of the tower. Condensate would require collection/treatment/disposal.	Eliminated due to energy requirements (approximately 4.7 watts per gallon as opposed to 1.7 watts per gallon for air stripping).

TABLE A-2
SCREENING OF REMEDIAL ACTION TECHNOLOGIES

BADGER ARMY AMMUNITION PLANT
BARABOO, WISCONSIN
(continued)

GROUNDWATER/SURFACE WATER

RESPONSE CATEGORY/ CORRECTIVE ACTION TECHNOLOGY	SITE-LIMITING CHARACTERISTICS	WASTE-LIMITING CHARACTERISTICS	SCREENING STATUS
Carbon Adsorption	None.	Suspended solids may require removal prior to treatment to avoid clogging carbon bed.	Retained for treatment of volatile organic compounds. Currently implemented on site.
Wet Air Oxidation	Energy source required to produce heat.	Not economical for dilute organic wastestreams (<1%). Current applications include wastewater and wastewater sludges to reduce COD and destroy dilute organics.	Eliminated; effectiveness at full-scale operations not proven.
Supercritical Water Oxidation	Energy source required to produce heat.	Not economical for dilute organic wastestreams (<1%). Current applications include wastewater and wastewater sludges to reduce COD and destroy dilute organics.	Eliminated; effectiveness at full-scale operations not proven.
Thin Film Evaporation	None.	Process produces a concentrated wastestream requiring treatment. Process not proven effective for organics in groundwater at BAAP.	Eliminated due to presence of organics in groundwater.
Reverse Osmosis	None.	Suspended solids and inorganics may foul or clog membrane. Process produces a concentrated wastestream requiring treatment.	Eliminated. Extensive pretreatment required to prevent membrane deterioration and fouling. Reject stream is typically high percentage of feed flow.
Resin Adsorption	None.	Process produces a concentrated wastestream requiring treatment.	Eliminated due to presence of chlorinated organics in groundwater at BAAP.
Biological Treatment	None.	Chlorinated organics are difficult to treat biologically.	Retained.
Ion Exchange	None.	Effective for removal of inorganics. Often used in combination with precipitation/flocculation as a method to reduce sludge production. Not effective for organics.	Retained for treatment of inorganics and nitrates.

TABLE A-2
SCREENING OF REMEDIAL ACTION TECHNOLOGIES

BADGER ARMY AMMUNITION PLANT
BARABOO, WISCONSIN
(continued)

GROUNDWATER/SURFACE WATER

RESPONSE CATEGORY/ CORRECTIVE ACTION TECHNOLOGY	SITE-LIMITING CHARACTERISTICS	WASTE-LIMITING CHARACTERISTICS	SCREENING STATUS
In Situ Treatment			
In Situ Biological	Site-specific information regarding hydrogeologic characteristics and any microorganism growth-limiting factors must be collected to determine site-limiting characteristics for biodegradation.	Some chlorinated organics will biodegrade only under aerobic conditions while others will biodegrade only under anaerobic conditions.	Retained as the only treatment potentially capable of treating organics in-situ.
Ancillary			
Aeration	None.	Volatile organic emissions may need to be controlled.	Retained as a pretreatment step for groundwater treatment.
Filtration	None.	High concentrations of inorganics and suspended solids may result in the need for excessive backwashing of filter.	Retained as a pretreatment step for groundwater treatment.
Precipitation/Flocculation/ Sedimentation	None.	Concentrated sludge would require treatment/disposal.	Retained as a pretreatment step for groundwater treatment.
Dewatering	None.	None.	Retained as a predisposal step for sludge produced by water treatment.
Disposal/Discharge			
RCRA Landfill (off-site)	None.	Must comply with Land Disposal Restrictions.	Retained for disposal of sludge and spent activated carbon.
Incineration (off-site)	None.	None.	Retained for regeneration of activated carbon.
Groundwater Reinjection (on-site)	Infiltration of treated groundwater could affect the migration of contaminants.	None.	Retained for recirculating groundwater not meeting NPDES limits within zone of contamination.

TABLE A-2
SCREENING OF REMEDIAL ACTION TECHNOLOGIES

BADGER ARMY AMMUNITION PLANT
BARABOO, WISCONSIN
(continued)

GROUNDWATER/SURFACE WATER			
RESPONSE CATEGORY/ CORRECTIVE ACTION TECHNOLOGY	**SITE-LIMITING CHARACTERISTICS**	**WASTE-LIMITING CHARACTERISTICS**	**SCREENING STATUS**
Discharge to Surface Water	None.	NPDES discharge limits apply.	Retained. Treated groundwater from the existing treatment system is discharged to the Wisconsin River.

Notes:

BAAP - Badger Army Ammunition Plant
cm/sec - centimeters per second
COD - chemical oxygen demand
DNT - dinitrotoluene
NCP - National Contingency Plan
NPDES - National Pollution Discharge Elimination System
RCRA - Resource Conservation and Recovery Act
RF - Radio Frequency
UV - ultraviolet

APPENDIX C

LOCATION-SPECIFIC AND CHEMICAL-SPECIFIC ARARS

APPENDIX C.1: SUMMARY OF FEDERAL ARARS AND GUIDANCE MATERIALS

Clean Water Act (CWA)

The Clean Water Act (CWA) was enacted to restore and maintain the quality of surface waters. The CWA regulations that are most likely to be Applicable or Relevant and Appropriate Requirements (ARARs) for Superfund actions are the requirements for:

- Surface water quality (Quality Criteria for Water)
- Direct discharges to surface waters (National Pollutant Discharge Elimination System)
- Indirect discharges to publicly-owned treatment works (National Pretreatment Program)
- Discharges of dredge-and-fill materials to surface waters, (Guidelines for Specification of Disposal Sites for Dredged or Fill Material)

Each of these regulations, in addition to the regulations governing discharge of radioactive pollutants to surface waters and oil pollution control are discussed in the following paragraphs. There are three categories of pollutants regulated under the various parts of the CWA as listed below:

- <u>Toxic pollutants</u> identified in CWA Section 307(a)(1);
- <u>Conventional pollutants</u> including biochemical oxygen demand (BOD), total suspended solids (TSS), fecal coliform, oil and grease, and pH (CWA Section 304(a)(4); and
- <u>Nonconventional pollutants</u>, which are defined as any pollutant not identified as either conventional or toxic in accordance with 40 CFR 122.21(1)(2).

CWA, Ambient Water Quality Criteria; 40 CFR Part 131

Federal Ambient Water Quality Criteria (AWQC) under the CWA are non-enforceable guidelines established by the USEPA for evaluating toxic effects on human health and aquatic organisms. AWQC are used or considered by the states in setting their water quality standards.

AWQC may be potential ARARs for groundwater in instances where Maximum Contaminant Levels (MCLs) or Maximum Contaminant Level Goals (MCLGs) are not sufficiently stringent to be protective of the environment. In instances where the contaminants present an environmental concern, the MCLs and MCLGs should be compared, and the more stringent should be considered as the potential relevant and appropriate requirement for the site. However, while it is possible to derive cleanup levels for drinking water from AWQC, these values are not intended to be used as drinking water cleanup standards because no criteria are provided for human exposure from ingestion of water alone. Carcinogens, which have a AWQC of zero, are not considered relevant and appropriate because they cannot be measured. This policy is consistent with the zero value for MCLGs under the Safe Drinking Water Act (SDWA). AWQC for noncarcinogens are generally set above zero, and address chronic and toxic effects. Table C-1 lists the AWQC published for two human exposure scenarios as well as acute and chronic toxicity for freshwater aquatic life.

In the absence of any Wisconsin Surface Water Quality Standard (FWQS) specific to the pollutant and water body of concern, AWQC may be ARARs for surface water bodies when protection of aquatic life is a concern or if human exposure from consumption of contaminated fish is a concern.

Clean Water Act, 40 CFR Part 122, 125 - National Pollutant Discharge Elimination System (NPDES)

The CWA controls the direct discharge of pollutants to surface water through the National Pollutant Discharge Elimination System (NPDES) program. NPDES requires permits for direct discharges to surface waters. The permits contain limits based on either effluent standards or AWQC if they are more stringent. An on-site discharge from a Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) site to surface waters must meet the substantive NPDES requirements, but need not obtain an NPDES permit to comply with the administrative requirements of the permitting process, consistent with CERCLA Section 121(e)(1). On the other hand, an off-site discharge from a CERCLA site to

TABLE C-1
CHEMICAL-SPECIFIC STANDARDS AND GUIDANCE FOR GROUNDWATER AND SURFACE WATER

FEASIBILITY STUDY
BADGER ARMY AMMUNITIONS PLANT

CHEMICAL		SAFE DRINKING WATER ACT (SDWA) (a)		CWA WATER QUALITY CRITERIA (b)				WI PUBLIC HEALTH GROUNDWATER QUALITY STANDARDS (c)	
				FOR PROTECTION OF HUMAN HEALTH		FOR PROTECTION OF AQUATIC LIFE			
CHEMICAL CODE	CHEMICAL NAME	MCL (μg/L)	MCLG (μg/L)	WATER AND FISH CONSUMPTION (μg/L)	FISH CONSUMPTION ONLY (μg/L)	FRESHWATER ACUTE/CHRONIC (μg/L)	MARINE ACUTE/CHRONIC (μg/L)	ENFORCEMENT STANDARDS (μg/L)	PAL (μg/L)
AL	aluminum	50-200 (1)	-	(2)	(2)	(2)	(2)	-	-
ALK	alkalinity	-	-	-	-	- /20,000 ppm	-/-	-	-
AS	arsenic	50 (3)	-	0.0022	0.0175	-/-	-/-	50	5
B2EHP	bis(2-ethylhexyl) phthalate	-	-	15,000	50,000	400/300 (4)	400/360 (4)	3	0.3
BA	barium	2,000	2,000	1,000	-	-/-	-/-	2,000	400
BE	beryllium	4	4	0.0037	0.0641	130/5.3 (4)	-/-	-	-
C6H6	benzene	5	0	0.66	40	5,300/- (5)	5,100/700 (5)	5	0.5
CA	calcium	-	-	-	-	-/-	-/-	-	-
CCL4	carbon tetrachloride	5	0	0.4	6.94	35,200/- (5)	50,000/- (5)	5	0.5
CD	cadmium	5	5	10	-	3.9/1.1 (8)	43/9.3	5	0.5
CHCL3	chloroform	100 (6)	0	0.19	15.7	28,900/1,240(5)	-/-	6	0.6
CL	chloride	250,000 (1)	-	-	-	860,000/230,000	-/-	250,000 (1)	125,000 (1)
CR	chromium (total)	100	100	-	-	-/-	-/-	100	10
CU	copper	TT	1300	1300	-	18/12 (7)	2.9/-	1300	130
24DNT	2,4-dinitrotoluene	-	-	0.11	9.1	330/230 (5)	-/-	0.05	0.005
26DNT	2,6-dinitrotoluene	-	-	-	-	-/-	-/-	0.05	0.005
FE	iron	300 (1)	-	300	-	-/1,000	-/-	300 (1)	150 (1)
HG	mercury	2	2	0.144	0.146	2.4/0.012	2.1/0.025	2	0.2

continued

TABLE C-1
CHEMICAL-SPECIFIC STANDARDS AND GUIDANCE FOR GROUNDWATER AND SURFACE WATER

FEASIBILITY STUDY
BADGER ARMY AMMUNITIONS PLANT

CHEMICAL		SAFE DRINKING WATER ACT (SDWA) (a)		CWA WATER QUALITY CRITERIA (b)				WI PUBLIC HEALTH GROUNDWATER QUALITY STANDARDS (c)	
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K	potassium	-	-	-	-	-/-	-/-	-	-
MEC6H5	toluene	1,000	1,000	14,300	424,000	17,500/- (5)	6,300/5000 (5)	343	68.6
MG	magnesium	-	-	-	-	-/-	-/-	-	-
MN	manganese	50 (1)	200	50	100	-/-	-/-	50 (1)	25 (1)
NA	sodium	(7)	-	-	-	-/-	-/-	-	-
NAP	naphthalene	-	-	-	-	2,300/620 (5)	2,350/-	40	8
NH3	ammonia	-	-	(2)	(2)	(2)	(2)	-	-
NI	nickel	100	100	13.4	100	1,400/160 (8)	75/8.3	-	-
NIT	nitrite/nitrate-nonspecific	10,000 (9)	10,000 (9)	-	-	-/-	-/-	10,000	2,000
NNDPA	n-nitroso diphenylamine	-	-	4.9	16.1	-/-	-/-	-	-
NO2	nitrite	1,000	1,000	-	-	-/-	-/-	1,000	200
NO3	nitrate	10,000	10,000	10,000	-	-/-	-/-	10,000	2,000
PB	lead	TT (10)	0	50	-	83/3.2 (8)	220/8.5	15	1.5
SE	selenium	50	50	10	-	20/5	300/71	50	10
SO4	sulfate	250,000 (1)	-	-	-	-/-	-/-	250,000 (1)	125,000 (1)
111TCE	1,1,1-trichloroethane	200	200	18400	1,030,000	-/-	31,200/- (5)	200	40

TABLE C-1
CHEMICAL-SPECIFIC STANDARDS AND GUIDANCE FOR GROUNDWATER AND SURFACE WATER

FEASIBILITY STUDY
BADGER ARMY AMMUNITIONS PLANT

CHEMICAL		SAFE DRINKING WATER ACT (SDWA) (a)		CWA WATER QUALITY CRITERIA (b)				WI PUBLIC HEALTH GROUNDWATER QUALITY STANDARDS (c)	
				FOR PROTECTION OF HUMAN HEALTH		FOR PROTECTION OF AQUATIC LIFE			
CHEMICAL CODE	CHEMICAL NAME	MCL (μg/L)	MCLG (μg/L)	WATER AND FISH CONSUMPTION (μg/L)	FISH CONSUMPTION ONLY (μg/L)	FRESHWATER ACUTE/CHRONIC (μg/L)	MARINE ACUTE/CHRONIC (μg/L)	ENFORCEMENT STANDARDS (μg/L)	PAL (μg/L)
112TCE	1,1,2-trichloroethane	5	3	0.6	41.8	-/9,400 (5)	-/-	0.6	0.06
TDS	total dissolved solids	500,000 (1)(11)	-	-	-	-/-	-/-	-	-
TRCLE	trichloroethylene	5	0	2.7	80.7	45,000/21,900 (5)	2,000/- (5)	5	0.5
ZN	Zinc	5000 (1)	-	-	-	120/110 (8)	95/86 (8)	5,000 (1)	2,500 (1)

Sources:

(a) U.S. Environmental Protection Agency (EPA), 1993, "Drinking Water Regulations and Health Advisories." Office of Water, Washington, D.C. May 1993.

(c) Wisconsin Administrative Code, Chapter NR 140.10, Tables 1 and 2.

(b) EPA, 1991. "Water Quality Criteria Summary"; Office of Science and Technology, Health and Ecological Criteria Division, Ecological Risk Assessment Branch, Human Risk Assessment Branch; Washington, D.C. May 1, 1991.

Notes:

(1) Secondary drinking water standards, suggested level
(2) Criteria are pH dependent. Refer to 53FR33178.
(3) MCL for arsenic currently under review.
(4) Proposed value.
(5) Insufficient data to develop criteria. Value presented is the lowest observed effect level.
(6) Standard indicated is proposed value for total trihalomethanes (i.e., chloroform, dibromo-chloromethane, bromodichloromethane, and bromoform).
(7) No MCL has been set for sodium. However, a reporting level of 20,000 μg/l has been established. Monitoring is required and data is reported to health officials to protect individuals on restricted sodium diet.
(8) Hardness dependent criteria (100 mg/l $CaCO_3$ used).
(9) Standard indicated is for total nitrite/nitrate.
(10) Treatment technique requirement in effect. Action level for lead is 15 μg/L; for copper, 1,300 μg/L.
(11) The Preventative Action Limit for total dissolved solids (TDS) is 200,000 μg/l above an established background concentration (NR 140.20, Table 3); there is no Enforcement Standard for TDS.

Acronyms:

CWA	Clean Water Act
EPA	United States Environmental Protection Agency
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant level Goal
TT	Treatment technique
μg/L	micrograms per liter, equivalent to parts per billion
mg/L	milligrams per liter, equivalent to parts per million
PAL	Preventative Action Limit
SDWA	Safe Water Drinking Act
TDS	Total Dissolved Solids
WDNR	Wisconsin Department of Natural Resources

surface waters is required to obtain an NPDES permit and to meet both the substantive and administrative NPDES requirements. Examples of direct discharges include:

- On-site waste treatment whereby wastewater (which may include contaminated groundwater which is pumped, treated, and discharged to surface water) is discharged into or very close to a surface water body through a discernable conveyance such as a pipe, ditch, channel, tunnel, or well.

- Off-site treatment whereby wastewater is discharged by a discernible conveyance to an off-site surface water body.

- Any remedial action where site runoff is channeled directly to a surface water body through a ditch, culvert, storm sewer, or other means.

- Unchanneled runoff from a site into surface water.

Clean Water Act, 40 CFR Part 403, Section 307 (b) - National Pretreatment Program

If a groundwater treatment system is installed at the site and the discharge is to be sent to a publicly owned treatment works (POTW), then pretreatment standards under the federal CWA apply. CWA Section 307(b) authorized the National Pretreatment Program to regulate the introduction of pollutants from nondomestic sources into POTWs. The goal of the program is to prevent discharges into POTWs that (1) will interfere with the operation of a POTW, including interferences with sludge use or disposal; (2) will pass through the POTW; or (3) will be otherwise incompatible with the POTW. The National Pretreatment Program consists of the following interacting elements:

- national categorical standards

- prohibited discharge standards

- local limitations

Because the national categorical standards provide limits on discharges from particular industries, they are not applicable to the site. The prohibited discharge

standards consist of general prohibitions, specific prohibitions, and local limitations, and are discussed in the following subsections.

General Prohibitions

General prohibitions of pretreatment regulations (40 CFR Section 403.5(a)) are intended to control the introduction of certain contaminants into POTWs to (1) prevent interference with POTW operation, (2) prevent passage of contaminants through the POTW, and (3) improve opportunities to recycle and reclaim municipal and industrial wastewater and sludge.

Specific Prohibitions

Specific prohibitions of the National Pretreatment Program (40 CFR Section 403.5(6)) are intended to protect against discharges that cause (1) fire or explosion hazards, (2) corrosive structural damage to a POTW, (3) obstruction of flow into a sewer system, (4) interference due to a pollutant's high concentration, or (5) a temperature increase that would inhibit biological activity at a POTW.

Local Limitations

Local limitations are specific requirements developed and enforced by POTWs. POTWs develop limitations to meet state and local regulations in conjunction with general and specific prohibitions. These limitations should be periodically reviewed and revised to respond to changes in federal or state regulations or criteria, or plant operations at the POTW. For POTWs to develop local limitations, the statutory and regulatory requirements of the CWA and General Pretreatment Regulations and state and local requirements must be addressed.

Quality Criteria for Water; 40 CFR Part 131

Federal AWQC are nonenforceable, health-based criteria developed for 95 carcinogenic and noncarcinogenic compounds. AWQC were developed under CWA Section 304 and are used by the state, in conjunction with a designated use for the surface water body, to establish water quality standards under CWA Section 303. AWQC provide levels of exposure which are protective of human health from drinking the water and consuming aquatic life. AWQC also provide acute and chronic concentrations for protection of freshwater and marine organisms.

AWQC for noncarcinogens are generally set above zero, and address chronic and toxic effects. AWQC for carcinogens are recommended at zero. Table B-1 lists the AWQC published for two human exposure scenarios as well as acute and chronic toxicity for freshwater aquatic life.

Remedial actions involving contaminated surface water or groundwater must consider water uses and the circumstances of the release or threatened release. If a groundwater treatment system is installed at the site and the discharge from this system is sent to an on-site surface water body, the federal AWQC must be attained when relevant and appropriate under the circumstances of the release or the threatened release. Because compliance with AWQC is not legally required at non-Superfund sites, they are not legally applicable requirements under CERCLA.

In the absence of any Wisconsin FWQS specific to the pollutant and water body of concern, AWQC may be ARARs for surface water bodies when protection of aquatic life is a concern or if human exposure from consumption of contaminated fish is a concern. When protection of aquatic life is a concern, the AWQC for fresh or saltwater aquatic life may be ARARs. When human exposure from consumption of contaminated fish is a concern, the AWQC for human exposure from consumption of fish may be ARARs for the site. AWQC are rarely determined to be ARARs for surface water or groundwater determined to be a potential current or future source of potable water. However, if contamination of a potential potable water source also presents an environmental concern, the stringency of AWQC may be compared to non-zero MCLs or MCLGs, and the more stringent of the two may be the relevant and appropriate requirement for the site.

Again, AWQC may be potential relevant and appropriate ARARs for groundwater in instances where MCLs or MCLGs are not sufficiently stringent to be protective of the environment. In instances where the contaminants present an environmental concern, the MCLs and MCLGs should be compared, and the more stringent should be considered as the potential relevant and appropriate requirement for the site. However, while it is possible to derive cleanup levels for drinking water from AWQC, these values are not intended to be used as drinking water cleanup standards, because no criteria are provided for human exposure from ingestion of water alone. Carcinogens, which have a AWQC of zero, are not considered relevant and appropriate because they cannot be measured. This policy is consistent with the zero value for MCLGs under the SDWA.

Clean Water Act, 40 CFR Part 230 - Guidelines for Specification of Disposal Sites for Dredged or Fill Materials

The CWA regulates the discharge of dredged or fill material into U.S. waters, including wetlands. The U.S. Army Corps of Engineers (USACE) defines wetlands as those areas that are inundated or saturated by surface water or groundwater at a frequency and duration sufficient to support and, that under normal circumstances, do support a prevalence of vegetation typically adapted for life in saturated soil conditions. The purpose of Section 404 is to ensure that proposed discharges are evaluated with respect to impact on the aquatic ecosystem. The act of excavation and/or dredging is not regulated under Section 404; however, the deposition of dredged or excavated materials in U.S. waters, including wetlands, is. Discharge of fill material generally includes, without limitation, placement of fill necessary for construction and site development (e.g., dams, dikes, and levees), fill associated with the creation of ponds, and any other work involving fill material discharge. If a remedial alternative involves a dredged or fill material being discharged to a wetland, USACE permit requirements must be attained.

No procedures are set forth in the regulations for jurisdictional determination. Therefore, to determine if an area is subject to wetlands jurisdiction and permitting requirements, the closest USACE district office should be consulted. However, USACE, in conjunction with the U.S. Fish and Wildlife Service (USFWS), USEPA, and the U.S. Department of Agriculture Soil Conservation Service, developed the Federal Manual for Identifying and Delineating Jurisdictional Wetlands, which presents a multi-parameter approach to field identification of federally regulated wetlands (Department of the Army et al., 1989). For an area to meet the USACE definition of a wetland, it must contain hydrophytic vegetation and hydric soils, and have a hydrology indicative of a wetland. The size of the wetland is not a factor.

In addition, Section 404(b)(1), Guidelines for Specification of Disposal Sites for Dredged or Fill Material (40 CFR Part 230), maintains that no dredged or fill material discharge will be permitted if there is a practicable alternative with less impact on the aquatic ecosystem. Discharge also will not be permitted unless steps are taken to minimize potential adverse impacts, or if the discharge will cause or contribute to significant degradation of U.S. waters. If a remedial alternative involves discharging dredged or fill material to a wetland, potential short- and long-term effects must be determined, based on various physical, chemical, and biological parameters. Impacts to the following areas need to be addressed: substrate, suspended particulates, turbidity, water, current patterns and water circulations, normal water fluctuations, salinity, threatened and endangered species, fish or other

aquatic organisms in the food web, and other wildlife. Effects on human use characteristics (e.g., aesthetics and recreation) also need to be addressed.

Clean Water Act, 40 CFR Part 112 - Oil Pollution Control

Under these regulations, onshore and offshore oil storage facilities that could potentially spill oil into navigable U.S. waters or onto adjoining shorelines are required to prepare and implement a Spill Prevention, Control, and Countermeasure (SPCC) plan. Specifications for secondary containment and/or diversion structures, discharge systems, and leak detection systems are outlined. Facilities that have an aggregate storage of 1,320 gallons of oil or less, provided no single container has a capacity exceeding 660 gallons, are exempt from these regulations. These requirements may be potential ARARs for sites that include underground storage tanks.

Endangered Species Act (ESA), 40 CFR Part 302 (h)

With the vast acreage of undeveloped land available, many Army installations serve as habitat for native and migratory species including threatened and endangered flora and fauna. The Endangered Species Act (ESA) of 1973, as amended in 1988, governs the management of these resources and requires that proposed federal actions do not jeopardize the continued existence of endangered or threatened species or result in the destruction of critical habitat. For example, if under the ESA a baseline survey identifies listed species or areas of critical concern, a biological assessment may be required to evaluate potential adverse impacts caused by a proposed action or project.

Fish and Wildlife Coordination Act, 40 CFR 302 (g)

The Fish and Wildlife Coordination Act requires that the USFWS, National Marine Fisheries Service, and other related state agencies be consulted before a body of water, including wetlands, is modified (i.e., dredged, filled, or dammed). During the development of the site Feasibility Study (FS), alternatives proposing excavation or fill in or adjacent to a wetland will be evaluated with respect to potential impacts on wetlands.

In addition, under the Sikes Act, each military department must provide for proper fish and wildlife management. Furthermore, the Act requires resource management be carried out according to a cooperative plan mutually agreed upon by the installation commander, the regional office of the U.S. Fish and Wildlife Service, and the appropriate state agency. This Act also provides for collection of hunting and fishing fees to provide habitat improvements.

Floodplain Management Exec. Order No. 11988; (40 CFR 6.302(b) and Appendix C

This executive order requires federal agencies to evaluate the potential effects of adverse impacts to floodplains associated with direct and indirect development of a floodplain. Alternatives that involve the alteration of a floodplain may not be selected unless a determination is made that no practicable alternative exists. If no practicable alternative exists, potential harm must be minimized and action taken to restore and preserve the natural and beneficial values of the floodplain.

Hazardous Materials Transportation Act, 49 CFR Parts 171, 173, 178, 179; Hazardous Materials Transportation Regulations

This regulation outlines procedures for the packaging, labeling, manifesting, and transporting of hazardous materials. Contaminated materials would need to be packaged, manifested, and transported to a licensed off-site disposal facility in compliance with these regulations.

National Environmental Policy Act Regulations, 40 CFR Part 6

Appendix C of the National Environmental Policy Act (NEPA) sets forth policy for carrying out provisions of the Protection of Wetlands Executive Order (EO 11990). Under this order, federal agencies are required to minimize the degradation, loss, or destruction of wetlands, and to preserve and enhance natural and beneficial values of wetlands. Appendix C requires that no remedial alternative adversely affect a wetland if another practicable alternative is available. If no alternative is available, impacts from implementing the chosen alternative must be mitigated. During the site FS process, identification and evaluation of alternatives involving excavation, excavation transport, or fill in or adjacent to a wetland will address the alternative's impact on the wetland as it relates to NEPA.

Protection of Wetlands Exec. Order No. 11990; 40 CFR 6.302(a) and Appendix C

This executive order requires federal agencies to avoid, to the extent possible, the adverse impacts associated with the destruction or loss of wetlands and to avoid support of new construction in wetlands if a practical alternative exists. Alternatives that involve the alteration of a wetland may not be selected unless a determination is made that no practicable alternative exists. If no practicable alternative exists, potential harm must be minimized and action taken to restore and preserve the natural and beneficial values of the wetland.

Resource Conservation and Recovery Act (RCRA), Hazardous Waste Management System; (40 CFR Part 260)

This rule sets forth procedures that USEPA will use to make information available to the public, and sets forth rules that transfer storage and disposal facilities must follow to assert claims of business confidentiality with respect to information submitted to USEPA pursuant 40 CFR Parts 261-265. This rule creates no substantive cleanup requirements.

RCRA, 40 CFR - Part 264 Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities

This rule establishes minimum national standards which define the acceptable management of hazardous wastes for owners and operators of facilities which treat, store or dispose of hazardous wastes. Should remedial actions involve management of RCRA wastes at an off-site TSDF or if a treatment facility is constructed on-site, these requirements would be applicable.

RCRA, 40 CFR Subpart B, 264.10-264.18 - General Facility Standards

These general facility requirements outline general waste analysis, security measures, inspections, and training requirements. Section 264.18 establishes that a hazardous waste facility located in a 100-year floodplain be designed, constructed, operated, and maintained to prevent washout of hazardous wastes during a 100-year flood. An exception is if it can be demonstrated that current procedures can facilitate the safe removal of waste (before floodwaters would reach the facility) to a location where

waste is not vulnerable to floodwaters. Should remedial actions involve management of RCRA wastes at an off-site TSDF, if a treatment facility is constructed on site, or if the 100-year floodplain may be impacted, these requirements may be potential relevant and appropriate ARARs.

RCRA, 40 CFR Sections 264.90-264.101, Subpart F - Releases from Solid Waste Management Units

The RCRA concentration limits (40 CFR Section 264.94) are potentially applicable and establish three categories of groundwater protection standards: background concentrations, RCRA MCLs, and Alternate Concentration Limits (ACLs). RCRA MCLs consist of a subset of SDWA MCLs; therefore, in complying with SDWA MCLs, cleanup will be consistent with RCRA MCLs. If no MCL exists, a background level or a health-based (i.e., assuming human exposure) ACL may be developed on a case-by-case basis as a groundwater protection standard. ACLs are based on the contaminant level's potential adverse effects on groundwater quality and on hydraulically connected surface waters, considering factors such as (1) physical and chemical characteristics of the waste, (2) hydrogeological characteristics of the setting, (3) groundwater flow quantity and direction, (4) current and future groundwater uses, (5) existing quality of area groundwater, and (6) persistence and permanence of adverse effects. Additional factors are listed in 40 CFR Section 264.94. This rule is relevant and appropriate for cleanup of groundwater contamination at facilities holding a RCRA Part B permit for the treatment, storage, and disposal of hazardous waste.

RCRA, 40 CFR Subpart K, 264.220-264.231 - Surface Impoundments

There are three basic closure options for surface impoundments. The clean-closure option requires removal or decontamination for all hazardous constituents; it includes very stringent groundwater standards for cleanup levels. If all hazardous constituents will not be removed or decontaminated, the landfill closure option may be used. Landfill closure is a containment option and requires a final cover or cap and a post-closure plan that protects human health and the environment.

Should a remedial action involve the placement of hazardous wastes in surface impoundments (e.g., lagoons for the treatment and/or storage of extracted water/groundwater), this regulation would be relevant and appropriate.

RCRA, 40 CFR Sections 264.300-264.317, Subpart N - Landfills

This regulation covers design and operating requirements, and closure and post-closure options for hazardous waste landfills. These requirements must be considered and complied with during the development and implementation of remedial alternatives for the site landfills to contain hazardous waste. If closure is implemented as a remedial action, a final cover must be designed and constructed that prevents migration of liquids, requires minimum maintenance, promotes drainage, minimizes erosion, accommodates settling, and has a permeability less than or equal to that of any bottom liner or natural subsoils present.

Rivers and Harbors Act, Section 10

Section 10 of the Rivers and Harbors Act prohibits the unauthorized obstruction or alteration of any navigable water of the United States. This law would be applicable during any remedial activity which involved dredge-and-fill activities which could potentially affect navigable waters.

Safe Drinking Water Act (SDWA), 40 CFR Part 141 - National Drinking Water Regulations; Maximum Contaminant Level Goals

The SDWA MCLGs are ARARs for aquifers and related groundwater used as a potable water supply source. MCLGs are nonenforceable health goals established by USEPA; however, the 1990 National Contingency Plan (NCP) recognizes MCLGs as potential ARARs. MCLGs are used in cases in which multiple contaminants or pathways of exposure present extraordinary risks to public health. In such cases, USEPA makes a site-specific determination of the more stringent standards. Non-zero MCLGs are considered potential relevant and appropriate ARARs for groundwater used as a current or potential source of drinking water. The NCP established that MCLGs equal to zero are not appropriate for setting cleanup levels. In those circumstances the corresponding MCL will be the potentially relevant and appropriate requirement. An example of this approach is found in determining potential ARARs for copper and lead. The MCLG for copper is set at 1,300 μg/L, which is therefore the potential relevant and appropriate ARAR for copper. The MCLG for lead, on the other hand, was set at zero, which is not considered to be an "appropriate" standard for CERCLA cleanups. MCLGs are <u>never</u> applicable requirements at CERCLA sites because they are not enforceable. As discussed under MCLs, MCLGs could also be considered potential ARARs for surface water

if the water bodies under consideration are not current or potential sources of drinking water.

SDWA, 40 CFR Part 141 - National Drinking Water Regulations, Maximum Contaminant Levels

The SDWA MCLs are legally enforceable federal drinking water standards. MCLs are commonly identified as ARARs for existing or potential future drinking water sources. However, MCLs would only be applicable where water at a CERCLA site is delivered through a public water supply system; they would be relevant and appropriate ARARs for existing or potential drinking water sources where it is not part of a public water system. MCLs could also be potential ARARs for surface waters if the surface water bodies on or potentially affected by the site are not current or potential sources of drinking water.

SDWA, 40 CFR Part 143 - National Secondary Drinking Water Standards

This regulation establishes Secondary Drinking Water Standards, which are non-enforceable limits intended as guidelines for use by states in regulating water supplies. These values are listed in Table B-1 under the federal MCL column. Secondary drinking water criteria are identified with a "(2)" following the number.

TO BE CONSIDERED

USEPA Health Assessment Documents, Acceptable Intake, Chronic (AIC) and Subchronic (AIS)

The Acceptable Intake - Chronic (AIC) and Acceptable Intake - Subchronic (AIS) health assessment documents provide values developed for the risk reference dose (RfDs) and Health Effect Assessments (HEAs) for noncarcinogenic compounds. AIC and AIS values characterize the risks from these contaminants. This material provides guidance for assessing chronic and subchronic risks for noncarcinogenic compounds.

USEPA Human Health Assessment Cancer Slope Factors (CSFs)

Cancer Slope Factors (CSFs) are developed by the USEPA from HEA, or evaluation by the Human Health Assessment Group (HHAG). These values present the most up-to-date cancer risk potency information. HHAGs compute the individual cancer risk resulting from exposure to contaminants.

USEPA Office of Drinking Water, Health Advisories (HAs)

USEPA Health Advisories (HAs) are chemical concentrations based on estimates of risks due to consumption of contaminated drinking water. The HAs consider noncarcinogenic effects only, and should be considered for contaminants in groundwater used for drinking water.

Health advisories are estimates of risk due to consumption of contaminated drinking water. These advisories should be considered for contaminants in surface and groundwater which is or could potentially be used as a potable water source.

USEPA Reference Concentrations (RfCs)

Reference Concentrations (RfCs) are concentration levels developed by the USEPA for noncarcinogenic effects for lifetime exposure. RfCs values represent levels that, most likely, do not cause adverse effects to humans via inhalation of chemicals. RfCs are used to characterize risks of soil and groundwater contaminant exposure (for the inhalation exposure scenario).

USEPA Reference Doses

USEPA RfDs are dose levels also developed for noncarcinogenic effects. RfDs are considered the levels unlikely to cause significant adverse health effects associated with a threshold mechanism of action in human exposure. RfDs are typically employed to characterize risks of soil and groundwater contaminant exposure for the dermal contact and ingestion pathways.

USEPA Office of Water Guidance, Water-Related Fate of 129 Priority Pollutants (1979)

Presents chemical-specific fate and transport information for 129 priority pollutants. This document provides guidance to support the determination of contaminant fate and transport and is relevant to the site characterization, risk assessment, and fate and transport modeling components of the Remedial Investigation.

Interim Guidance on Establishing Soil Lead Cleanup Levels at Superfund Sites; [OSWER Directive #9355.4-02]

Sets forth interim soil cleanup levels for lead in lieu of any USEPA-verified toxicological values. Interim guidance recommends a cleanup level for total lead of 500 to 1,000 mg/kg. Site-specific conditions may warrant levels lower than 500 mg/kg, based on the exposure assessment.

APPENDIX C.2: SUMMARY OF WISCONSIN ARARS AND ADMINISTRATIVE CODE

Chapter NR 100; Environmental Protection

Chapter 100 outlines the discharge limits for both organic and inorganic mercury into state waters.

Chapter NR 102; Water Quality Standards for Wisconsin Waters

In conjunction with NR 103 to NR 105, this chapter establishes water quality standards for surface waters in the State of Wisconsin. This chapter describes the designated use categories for waters of the State and water quality criteria necessary to support these uses. The waters of the state are classified into fish and aquatic life categories described below:

- Great Lakes Communities: these waters include Lake Superior, Lake Michigan, and Green Bay and all associated bays, inlets, and spawning areas for anadromous fish species.

- Cold Water Communities: waters other than the Great Lakes communities which include surface waters capable of supporting cold water fish and other aquatic life or serving as a spawning area for such fish.

- Warm Water Sport Fish Communities: surface waters capable of supporting a community of warm water sport fish or serving as a spawning area for such fish.

- Warm Water Forage Fish Communities: surface waters capable of supporting abundant forage fish and other aquatic life.

- Limited Forage Fish Communities: surface waters of limited capacity and naturally poor water quality or habitat, capable of supporting only a limited community of forage fish and other aquatic life.

- Limited Aquatic Life: surface waters of severely limited capacity and naturally poor water quality or habitat which are capable of supporting only a limited community of aquatic life.

NR 102 states that all waters must meet the following conditions at all times and for all flow conditions:

- Substances which cause objectionable deposits on the shore or in the bed of a body of water must not be present.

- Floating or submerged debris, oil, scum, or other material must not be present.

- Materials that produce color, odor, taste, or unsightliness may not be present in amounts that interfere with public rights in state waters.

- Substances that are toxic or harmful to humans may not be present in amounts which are a significant public health threat or which are acutely harmful to animal, plant, or aquatic life.

Section NR 102.04(4) establishes the following criteria for all waters classified for fish and aquatic life:

- Dissolved oxygen content in the surface waters may not be lowered to less than 5 mg/L unless a variance in granted in accordance with Section NR 104.02(3).

- Temperature changes may not be so extreme that they adversely affect aquatic life. The maximum temperature rise at the edge of the mixing zone above the existing natural temperature may not exceed 5°F for streams and 3°F for lakes. The maximum allowable water temperature for warm water fish is 89°F.

- The range of pH must be within 6.0 to 9.0 with no change greater than 0.5 units outside seasonal minimum or maximum.

- Unauthorized concentrations of substances that are toxic to fish or aquatic life are not permitted.

- Streams classified as trout waters or as great lakes or cold water communities may not be altered so as to affect background temperature and dissolved oxygen levels.

Section 102.14 sets threshold concentrations for several substances causing taste and odor in water.

Chapter NR 103; Water Quality Standards for Wetlands

These regulations establish water quality standards for wetlands. The rule outlines the conditions necessary to protect water quality related functions and values of wetlands. To this end, the rule specifies that water quality values which must be protected include:

- storm and flood water storage and retention of water level fluctuation extremes;

- hydrologic function including the maintenance of dry season stream flow, discharge of groundwater to a wetland, recharge of groundwater from a wetland to another area, and the flow of groundwater through a wetland;

- filtration or storage of sediments, nutrients, or toxic substances that would have an adverse impact on other the quality of other state waters;

- shoreline protection against erosion through the dissipation of wave energy and water velocity and anchoring of sediments;

- habitat for aquatic organisms in the food web;

- habitat for resident and transient wildlife species; and

- recreational, cultural, educational, scientific, and natural aesthetic values and uses.

Wetland functional values and the impact of a proposed activity upon those values is determined using standardized wetland ecological methods such as:

- Wetland Evaluation Techniques (FHWA/COE);
- Wisconsin Wetland Evaluation Methodology;
- Hollands-Magee (IEP/Normandeau);
- Minnesota Wetland Evaluation Methodology for North Central United States; and the
- Wisconsin Department of Natural Resources Rapid Assessment Method.

Chapter NR 104; Uses and Designated Standards (formerly Intrastate Waters - Uses and Designated Standards)

Surface water classifications and effluent limitations are established in this rule. Classification by hydrologic characteristics includes the hydrologic description of lakes, diffused surface waters, wetlands, wastewater effluent channels, noncontinuous streams, and continuous streams. Effluent limitations for surface waters significant to the environmental integrity of the state or classified for fish and aquatic life, and wastewater treatment lagoons are also defined.

Chapter NR 106; Wisconsin Water Quality Standards; Procedures for Calculating Water Quality-based Effluent Limitations for Toxic and Organoleptic Substances Discharged to Surface Water

Wisconsin procedures for calculating effluent limitations are applicable to point sources that discharge wastewater containing toxic or organoleptic substances to surface waters. These regulations outline the calculations and data requirements necessary to calculate effluent limitations. If an alternative proposes to discharge treated groundwater at a surface water body at BAAP, these requirements may apply.

Chapter NR 108; Wisconsin Water Quality Standards; Requirements for Plans and Specifications Submittal for Renewable Projects and Operations of Community Water Systems, Sewerage Systems, and Industrial Wastewater Facilities

This rule establishes protocols for plan reviews and standards for treatment facilities in order to meet effluent standards.

Chapter NR 109; Wisconsin Water Quality Standards; Safe Drinking Water

This rule establishes water quality standards for potable water. These standards apply to all new and existing public water systems. A public water system, under the definition provided in this rule, means any system that has at least 15 service connections. Because BAAP waters are not used as a drinking water source, this rule will not be considered during the FS and remedial actions.

Chapter NR 115; Wisconsin's Shoreland Management Program

Chapter NR 115 requires counties to establish shoreland ordinances for all unincorporated shoreland areas. Shorelands are defined as the areas within 1,000 feet of a lake, pond, or flowage, or within 300 feet of rivers or streams or the floodplain. Each county must adopt regulations that meet or exceed minimum state standards to protect water resource values: natural beauty, water quality, recreation and navigation, and fish and wildlife. At a minimum, the ordinances must include (1) minimum lot sizes; (2) building setbacks from property lines and waterways; (3) controls on cutting trees and shrubbery; (4) standards for filling, grading, lagooning, dredging, ditching, and excavating; and (5) restrictions on improvements to older structures or uses that do not meet shoreland standards.

As specified in Chapter NR 115, Sauk County has adopted the Sauk County Shoreland Protection Ordinance (Sauk County Code of Ordinances, Chapter 8). This ordinance defines minimum lot sizes, building setbacks, restrictions to existing structure modification, controls on tree cutting, standards for fill, grading, lagooning, dredging, ditching, and excavating. This regulation may be applicable if any site-specific FS actions involved any of these activities at defined shorelands or wetlands. The shorelands/wetlands district includes all shorelands within the jurisdiction of this ordinance which are wetlands of 5 acres or more (excluding point symbols), and which are shown on the Wisconsin Wetland Inventory Maps that are adopted and made a part of this ordinance. A portion of a wetland less than 5 acres in size, and which is located in the unincorporated shoreland area within the county, shall be included in the shoreland/wetland district where the wetland as a whole is 5 acres or larger, but extends across the corporate limits of a municipality, across the county boundary, or across the shoreland limits, so that the wetland is not regulated in its entirety by the county.

If an existing town shorelands ordinance is more restrictive than the county ordinance, the town ordinance prevails in respect to the greater restrictions but not otherwise.

Specifically, regarding setbacks, "Unless an existing development pattern exists, a setback of 75 feet from the ordinary high-water mark of an adjacent body of water to the nearest part of a building or structure shall be required for all building and structures, except piers, boat hoists, and boathouses."

Chapter NR 116; Wisconsin's Floodplain Management Program

This chapter regulates all construction activities in the floodplain. Any construction activity must be evaluated for impact on upstream flooding. Generally, no activities are allowed in the "floodway" including solid or hazardous waste disposal.

Chapter NR 117; Wisconsin's City and Village Shoreland-Wetland Protection Program

Chapter NR 117 requires cities and towns to establish shoreland-wetland zoning ordinances that create shoreland-wetland zoning districts for all wetlands of 5 acres or more, located in shorelands within the incorporated area of the city or village. The state, with input from cities and villages, developed inventory maps showing the location and type of all wetlands. Cities and villages have the option of zoning any wetland within their incorporated area, including wetlands that are smaller than 5 acres in size.

The State of Wisconsin defines a wetland as an area in which water is at, near, or above the land surface long enough to be capable of supporting aquatic or hydrophytic vegetation and which has soils indicative of wet conditions. The shoreland zone is defined as the area within 1,000 feet of a lake, pond, or flowage, or within 300 feet of a stream or the floodplain, whichever is greater.

Although local governments may enact more restrictive standards, the state permits the following uses in wetlands:

- recreation, such as hunting, fishing, trapping, and hiking
- forestry, including limited water level manipulation and some road construction
- harvesting of wild crops

- pasturing of livestock, including fence construction
- agricultural cultivation, including maintenance of existing drainage systems
- some limited construction of small buildings needed to support open space or wetland preservation uses
- pier, dock, and walkway construction
- development of parks, recreation areas, and fish and wildlife habitat improvement projects
- limited utility construction
- limited road construction for farming and forestry
- limited railroad construction

Some additional uses are allowed in cities and villages. Every shoreland-wetland zoning ordinance or zoning code must provide a system to issue land use or building permits.

Potential wetlands have been identified at five BAAP sites. Shoreland-wetland requirements will be addressed for those remedial alternatives evaluated during the FS process involving land use or construction within a wetland zoning district.

Chapter NR 140; Wisconsin Groundwater Quality Standards

Wisconsin groundwater quality standards apply to virtually all facilities, activities, and practices regulated by the state which may affect groundwater quality. Chapter NR 140 encompasses the following relevant areas:

(1) It establishes two separate numerical standards for a wide group of pollutants. These are enforcement standards and preventative action limits (PALs) (Chapter NR 140.10 and Chapter NR 140.12).

(2) It specifies scientifically valid procedures for determining if numerical standards have been attained or exceeded (Chapter NR 140.14).

(3) It specifies procedures for establishing points of standards compliance (WAC, Chapter NR 140.22).

(4) It establishes sets of ranges of responses required if a groundwater standard (PAL or enforcement standard is attained or exceeded [Chapters NR 140.24, NR 140.26, and NR 140.27]).

Under Chapter NR 140, two separate standards, an enforcement standard and a PAL, were developed for public health (NR 140.10) and public welfare (NR 140.12). Enforcement standards are set at concentrations greater than PALs.

PALs are developed by using a percentage of enforcement standards (i.e., 10 percent for carcinogenic compounds and 20 percent for noncarcinogenic compounds), and must be achieved if technically and economically feasible. The feasibility of complying with a PAL is determined on a case-by-case basis.

According to NR 140.22, when designing a facility, enforcement standards and PALs can be applied at the following locations:

- any point of current groundwater use
- any point beyond the boundary of the property on which the facility, practice, or activity is located
- any point within the property boundaries beyond the three-dimensional design management zone if one is established by the Wisconsin Department of Natural Resources (WDNR) at each facility, practice, or activity

For spills, discharges, and other remedial response actions, the point of standards application is every point at which groundwater is monitored to determine if a PAL or enforcement standard has been attained or exceeded.

Sections NR 140.24, and NR 140.26 delineate the range of remedial responses required after verification that PALs and enforcement standards are exceeded, respectively. In both sections, notification and evaluation criteria are presented. The difference in response requirements between NR 140.24 and NR 140.26 mainly are that WDNR, under NR 140.24, has the latitude to require no action, additional sampling, or further testing/study actions if a PAL is exceeded or attained. Under NR 140.24, the WDNR may also require the following responses:

- Revise the operational procedures at the facility, practice, or activity.
- Change the design or construction of the facility, practice, or activity.
- Develop an alternate method of waste treatment or disposal.
- Prohibit or close and abandon a facility, practice, or activity.
- Conduct a remedial action to renovate or restore groundwater quality.
- Revise rules or criteria on facility design, location, or management practices.

Under Chapter NR 140.26, if a determination is made that an enforcement standard is violated at a point of compliance, WDNR requires one of the above actions with no exceptions (i.e., no provision for a no action response).

Section NR 140.27 states that attainment or exceedance of an enforcement standard at a point other than a point of compliance requires a response the same as for NR 140.24.

Chapter NR 200; Wisconsin Water Pollution Control Regulations; Applications for Discharge Permits

Permits are required for discharges of pollutants from point sources to surface waters and to land areas where pollutants may percolate, seep to, or be leached to groundwaters. Definitions are provided for in the Water Pollution Control Regulations (Parts 200-239) and describe the requirements for discharge permits.

Chapter NR 205; Wisconsin Water Pollution Regulations; General Provisions

The Wisconsin Pollutant Discharge Elimination System (WPDES) permit program is similar to the federal NPDES program under the CWA. Discharge of pollutants to waters of the state is prohibited without a valid WPDES permit. WDNR may impose monitoring, recordkeeping, and reporting requirements on the WPDES permit. Discharge standards are generally determined by the state on a case-by-case basis.

Chapter NR 215; Wisconsin Water Pollution Control Regulations; List of Toxic Pollutants

A list of toxic pollutants is provided in this chapter. According to the requirements of Chapter 147, Stats., all discharges containing these pollutants must not contain quantities of these pollutants greater than the amount which would remain after the discharge had received treatment by the best available technology economically achievable. Also, the quantities may also not exceed any lesser quantity necessary to provide an ample margin of safety, as determined by WDNR. Nearly all of the listed contaminants of concern for BAAP are included in this list of toxic pollutants.

Chapter NR 218; Wisconsin Water Pollution Control Regulations; Method and Manner of Sampling

This chapter provides the methods and manner for collection of effluent samples to comply with the monitoring requirements established in Chapter 147, Stats., and WPDES permits. Methods for measuring flow rate, calibration of flow measuring devices, location of sampling points, and size and storage of samples is addressed.

Chapter NR 219; Wisconsin Water Pollution Control Regulations; Analytical Test Methods and Sampling Procedure

Analytical test methods, preservation procedures, requirements for laboratories, and procedures applicable to effluent limitations for discharges point sources are established in this chapter.

Chapter NR 220; Wisconsin Water Pollution Control Regulations; Categories and Classes of Point Sources and Effluent Limitations

Categories and classes of point sources and effluent limitations are established in this rule. This chapter also lists industries for which standards have been established. Explosives manufacturing is included in this list.

Chapters NR 500-520; Wisconsin Solid Waste Management Regulations

These regulations outline requirements for solid waste landfill construction, operation, and closure. The requirements include performance and location standards, and design, operation, and closure criteria.

A solid waste landfill may not be located within 1,000 feet of any navigable lake, pond, or flowage; 300 feet of any navigable river or stream; a floodplain; 1,000 feet of the nearest edge of any state trunk highway, Interstate, or federal-aid primary highway, or the boundary of any public park unless the landfill is not visible; or 1,200 feet of any public or private water supply well. The location of a solid waste landfill also must not cause significant adverse impacts to wetlands critical habitat areas, surface water, or groundwater.

Remedial actions that involve closure of a landfill that contains nonhazardous solid waste must comply with the design requirements outlined in WAC, Chapter NR 504.07. In general, all final cover systems must be designed to minimize leachate generation, reduce facility maintenance by stabilizing the final surface through design of compatible slopes and vegetation, minimize climatic effects, and provide removal of leachate and venting of gas.

When closing a facility, the owner or operator must notify the WDNR in writing at least 120 days prior to closing and restrict access within 10 days of ceasing to accept waste. Closure should be accomplished in the following manner unless a different closure plan or plan of operation has been approved:

1. The entire area previously used for disposal purposes must be covered with at least 2 feet of compacted earth sloped adequately to allow surface water runoff.

2. Surface water run-on must be diverted around all areas used for waste disposal to limit the potential for erosion and increased infiltration. Drainage swales conveying surface water runoff over previous waste disposal areas must be lined with a minimum thickness of 2 feet of clay.

3. The final slopes of the facility must be greater than 2 percent, but must not exceed 3 horizontal to 1 vertical.

4. The finished surface of the disposal area must be covered with a minimum of 6 inches of topsoil.

5. The area must be vegetated within 90 days after ceasing to accept wastes or, if waste termination is after September 15, within 90 days after March 15 of the following year.

The WDNR may require the facility to have a gas venting system if necessary. Under Section NR 508.04, WDNR may require monitoring at existing facilities, regardless of whether the facility remains in operation. Specifications for monitoring are outlined. Sampling frequency for groundwater is based on the size of the facility. Leachate head wells must be measured at least monthly for leachate level elevations. Sampling parameters must be specified in writing by the WDNR.

Chapter NR 600; Hazardous Waste Management Rules; General

This chapter provides definitions for Wisconsin's Hazardous Waste Management Rules (Chapters NR 600-699) and general permit application information. Section NR 600.04 also specifies four prohibited activities:

- underground treatment of any hazardous waste through a well;
- land treatment of any hazardous waste;
- the use of solid waste, used oil, or other material which is contaminated or mixed with a hazardous waste for dust suppression or road treatment; or
- the placement of any noncontainerized or bulk hazardous waste in a salt dome formation, salt bed formation, underground mine, or cave.

This chapter also incorporates reference citations and general information concerning the hazardous waste management program.

Chapter NR 630; Wisconsin Hazardous Waste Management Rules; Storage, Treatment and Disposal Facility General Standards

This chapter specifies the general requirements that apply to the storage, treatment, and disposal of hazardous waste. Chapter NR 630.12 describes the requirement for general waste analysis for hazardous waste. This rule requires that an owner or operator of a hazardous waste facility conduct a detailed chemical and physical analysis of a representative sample of waste before treatment or disposal of any hazardous waste. Chapter NR 630.13 describes the waste analysis plan which must be prepared and followed by the owners and operators of a hazardous waste facility. This rule further specifies locations where a hazardous waste facility may not be located, including:

- Floodplains
- Wetlands
- Endangered species habitats
- Within 200 feet from facility property line without locking (subject to WDNR ruling)
- Within 200 feet of a fault which has had displacement during the Holocene Epoch.

The rule also establishes standards for open burning and detonation of explosives in NR 630.20. Table VII, in Section 623.20, establishes the minimum distance, from open burning or detonation of waste explosives or propellants, to the property owned by other persons.

Section NR 630.21 establishes preparedness and prevention measures required in the design, construction, maintenance, and operation of a hazardous waste facility. Requirements for a contingency plan are detailed in Section NR 630.22.

Chapter NR 635; Wisconsin Groundwater Standards for Hazardous Waste; Groundwater and Leachate Monitoring Standards and Corrective Action Requirements.

This rule specifies groundwater and leachate monitoring requirements, as well as corrective action requirements resulting from a monitoring program. Existing landfills or impoundments are defined as facilities having accepted hazardous waste after November 19, 1980 but not after July 26, 1982. The monitoring requirement for existing landfills is contained in Section 635.17. The requirements of Section NR 635.05 and 635.16 apply to all landfills, surface impoundments, and waste piles that accepted wastes after July 26, 1982.

Solid waste disposal facilities which are approved under NR 506.15 to accept hazardous waste only from very small quantity generators are exempted from this rule.

Chapter NR 660; Wisconsin Hazardous Waste Landfill Standards: Landfill and Surface Impoundment Standards.

This chapter applies to owners and operators of facilities that treat, store, or dispose of hazardous waste in landfills or surface impoundments. Specific location restrictions are given in Section NR 660.06. The chapter also discusses the requirements for initial site inspection and report, feasibility report, plan of operation, and minimum design requirements in Sections NR 660.07, 08, 09, 10, and 13, respectively.

Exemptions to this rule include surface impoundments which have discharges regulated under Chapter 147, a solid waste disposal licensed under Chapters 500 to 522, and facilities operating under interim licenses.

Chapter NR 670; Miscellaneous Hazardous Waste Standards; Miscellaneous Unit Standards

This chapter specifies requirements that apply to facilities that are not specified otherwise. Prior to establishing or constructing a miscellaneous unit, an operating license must first be issued following approval of a feasibility study and plan or operation report.

Standards for miscellaneous units are based on protection of human health and the environment that may be due to migration of waste constituents: in the groundwater or subsurface environment; in surface water, wetlands, or on the soil surface; and in the air. Parameters which must be considered are described in Section NR 670.08.

Requirements for thermal treatment facilities other than incinerators is addressed in Section NR 670.11.

Wisconsin Statutes Annotated, Chapter 30, Dredge and Fill Requirements

This statute outlines permit requirements for structures and deposits in Wisconsin navigable waters and for enlargement of waterways. These requirements will be considered and complied with when developing and implementing remedial actions at BAAP that involve navigable waters. Under Section 30.12, it is unlawful to deposit any material or to place any structure on the bed of any navigable water without a permit where no bulkhead line has been established or beyond a lawfully established bulkhead line. A structure must not materially obstruct navigation or

reduce the effective flood flow capacity of a stream, and must not be detrimental to the public interest.

Under Section 30.19, unless a permit has been granted, it is unlawful to construct, dredge, or enlarge any artificial or natural waterway, canal, channel, ditch, lagoon, pond, lake, or similar waterway where the purpose is ultimate connection with an existing navigable stream, lake, or other navigable waters, or where any part of the artificial waterway is located within 500 feet of the ordinary high-water mark of an existing navigable stream, lake, or other navigable waters. A permit is also required for grading or removing topsoil from the bank of any navigable stream, lake, or other body or navigable water where the area is exposed by the grading and where removal will exceed 10,000 square feet. Exceptions are granted for public highways, agricultural uses, lakes, and streams located in certain counties with a population of 750,000 or more, and any work required to maintain the dimensions of an enlarged waterway.

Chapter 30 also addresses bridge construction and maintenance, waterfowl habitat management, cutting weeds in navigable waters, wharves, piers, swimming rafts, diversions of water from lakes and streams, and removal of material from beds of navigable waters.

If the response action is conducted entirely on site, a permit would not be required.

City of Baraboo Floodplain Zoning Code (Subchapter II)

The Baraboo Floodplain Zoning Code divides floodplain areas into three districts: the Floodway District, the Flood Fringe District, and the General Floodplain District. The Floodway District is the channel of a stream and those portions of the floodplain adjoining the channel that are required to carry and discharge the floodwater or flood flows of any river or stream associated with the regional flood. The Flood Fringe District is the area between the regional flood limits and the floodway area. The General Floodplain District is the land that has been or may be hereafter covered by floodwater during the regional flood and encompasses both the Floodway and Flood Fringe districts.

Certain activities are prohibited or subject to specific restrictions in floodplain areas. Within the Floodway District, only open space having low flood damage potential and not obstructing flood flows is permitted, including agricultural uses, nonstructural industrial or commercial uses (e.g., parking lots), public and private recreational uses,

extraction of sand or gravel, marina- and boat-related structures, railroads, pipes, streets, and culverts. Specific standards for developments in floodway areas are listed.

In the Flood Fringe District, any structures, land use, or development may be permitted, provided a land use permit has been issued by the Building Inspector. Manufacturing and industrial buildings, structures, and accessory uses must be elevated or flood-proofed to 2 feet above the regional flood elevation. The storage or processing of materials that are buoyant, flammable, or explosive, or which in times of flooding could be injurious to human, animal, or plant life, must be at or above the flood protection elevation or flood-proofed. All solid waste disposal sites, whether public or private, are prohibited in flood fringe areas.

A building permit must be obtained for construction in a floodplain. Flood-proofing measures must be designed consistent with the flood protection elevation for the particular area associated with it. The applicant must submit a plan or document certified by a registered professional engineer or architect that the flood-proofing measures are adequately designed for protection to the flood protection elevation for the particular area. All flood-proofing must provide anchorage to resist flotation and lateral movement.

All zoning and permit requirements associated with activities within a floodplain will be considered if remedial or construction activities at BAAP involve work in a floodplain.

ACLs	Alternate Concentration Limits
AIC	Acceptable Intake - Chronic
AIS	Acceptable Intake - Subchronic
ARARs	Applicable or Relevant and Appropriate Requirements
AWQC	Ambient Water Quality Criteria
BOD	biochemical oxygen demand
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CSFs	Cancer Slope Factors
CWA	Clean Water Act
EO	Executive Order
ESA	Endangered Species Act
FS	Feasibility Study
FWQS	Surface Water Quality Standard
HA	Health Advisories
HEAs	Health Effects Assessment
HHAG	Human Health Assessment Group
MCL	Maximum Contaminant Level
MCLGs	Maximum Contaminant Level Goals
NEPA	National Environmental Policy Act
NCP	National Contingency Plan
NPDES	National Pollutant Discharge Elimination System
PAL	preventative action limits
POTW	publicly owned treatment works
RfC	Reference Concentration
RfD	Reference Dose
RCRA	Resource Conservation and Recovery Act
SDWA	Safe Drinking Water Act
SPCC	Spill Prevention, Control, and Countermeasure

GLOSSARY OF ACRONYMS

TDS	total dissolved solids
TSDF	transfer storage and disposal facility
TSS	total suspended solids
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
WAC	Wisconsin Administrative Code
WDNR	Wisconsin Department Natural Resources
WPDES	Wisconsin Pollutant Discharge Elimination System

APPENDIX D

PROPELLANT BURNING GROUND

APPENDIX D.1

MODIFICATION OF CONDITIONAL PLAN APPROVAL OF IN-FIELD CONDITIONS REPORT

PROPELLANT BURNING GROUND

BEFORE THE
STATE OF WISCONSIN
DEPARTMENT OF NATURAL RESOURCES
MODIFICATION OF CONDITIONAL PLAN APPROVAL
OF IN-FIELD CONDITIONS REPORT DATED SEPTEMBER 14, 1987
FOR
WASTE DISPOSAL SITES AT THE
BADGER ARMY AMMUNITION PLANT
SAUK COUNTY
WISCONSIN

FINDINGS OF FACT

General Information

Owner: United States Army
HY 12 South
Baraboo, Wisconsin 53913

Operator: Olin Corporation
Hy 12 South
Baraboo, Wisconsin 53913

Contact: David C. Fordham (608) 356 - 5525
Commanders Representative
Badger Army Ammunition Plant
Hy 12 South
Baraboo, Wisconsin 53913

Location: Sections 1,2,11,12,14,13, W 1/2 of Sec. 3, W 1/2 of Sec. 10, N 1/2 of Sec. 23, N 1/2 of Sec. 24, SE 1/4 of Sec. 34, T 10 N, R 6 E, Town of Sumpter and S 1/3 of Sec. 35, S 1/3 of Sec 36, T 11 N, R 6 E, Town of Sumpter: SW 1/4, SW 1/4 of Sec. 31, NW 1/4, SW 1/4 and SE 1/4 of Sec. 6, all but the NE 1/4 of Sec. 7, and Sec. 18, T 10 N, R 7 E, Town of Merrimac, Sauk County, Wisconsin.

Consultant: Asea Brown Boveri
261 Commercial Street
P.O. Box 7050
Portland, Maine 04112

The Department finds that:

1. The U.S. Army owns the following solid waste disposal and hazardous waste management and spill sites at Badger Army Ammunition Plant (BAAP):

   a. An existing landfill (DNR ID #2813) located in the NW 1/4 of the NW 1/4 of Section 6, T10N, R7E, Town of Merrimac, Sauk County, Wisconsin.

   b. The deterrent burning grounds (DNR ID #3037) located in the SW 1/4

of the NE 1/4 of Section 1, T10N, R6E, Town of Sumpter, Sauk County, Wisconsin.

c. The propellant burning grounds (DNR ID #2814) and EPA ID # WI9210020054 located in the E 1/2 of the NW 1/4 of Section 14, T10N, R6E, and the W 1/2 of the NE 1/4 of Section 14, T10N, R6E, Town of Sumpter, Sauk County, Wisconsin.

d. The wastewater settling lagoons (WPDES No. WI-0043974-2) located along the southern border of the BAAP property (N3500 , E6200 - E12500, BAAP coordinates), Town of Merrimac, Sauk County, Wisconsin.

e. The new acid area (DNR ID #2934) located in the SE 1/4, SE 1/4 of Section 12, T 10 N, R 6 E, Town of Sumpter, Sauk County, Wisconsin.

f. Other Solid Waste Management Units listed in the report "Certification Regarding Potential Releases from Solid Waste Management Units" submitted to the U.S. Environmental Protection Agency (EPA) by the BAAP on March 28, 1985 and in the final Master Environmental Plan (MEP) for BAAP prepared by Argonne National Laboratory, January 1988. These include: the Oleum Plant and Pond, the Old Acid Area, the Ballistics Pond, the Nitroglycerine Area and Pond, Landfill No. 1, and the Rocket Paste Area and Pond.

g. An operating landfill (DNR ID #3118) located in the SW 1/4 of the NW 1/4 of Section 7, T10N, R7E, Town of Merrimac, Sauk County, Wisconsin.

2. Olin Corporation is under contract to the U.S. Army to perform specified services at BAAP.

3. On September 14, 1987, the Wisconsin Department of Natural Resources (WDNR) issued an In-Field Conditions Report approval for the facility.

4. On October 30, 1988 the U.S. EPA issued a Resource Conservation and Recovery Act (RCRA) permit to BAAP for a hazardous waste storage unit in accordance with the applicable regulations contained in 40 CFR parts 260, 261, 264, 266, 268, 270 and 124 and the applicable provisions of the Hazardous and Solid Waste Amendments (HSWA) of 1984.

5. The RCRA permit contains requirements for implementation of Interim Measures in Task II of the 1988 RCRA permit.

6. On February 21, 1990, the WDNR issued a plan approval modification to the September 14, 1987 In-Field Conditions Report approval.

7. On March 13, 1990, the EPA provided BAAP comments on a Draft Phase I

report submitted by BAAP.

8. On March 13, 1990, BAAP submitted a "Public Involvement and Response Plan".

9. On March 23, 1990, the WDNR issued a "Propellant Burning Ground Groundwater Remedial Action WPDES Permit #WI-0046566-1" to BAAP to discharge treated groundwater (from the IRM system) to the Wisconsin River.

10. On April 12, 1990, BAAP notified the WDNR that its analytical contractor, metaTrace, Inc. was under investigation for falsifying laboratory data.

11. On June 12, 1990, BAAP discussed (by telephone) permit conditions for hi-capacity wells (for the IRM system), background sampling for BAAP,s WPDES permit, the frequency for measuring water levels in piezometers used to monitor the IRM system.

12. On July 3, 1990, BAAP notified the WDNR that the IRM treatment system was operational on a part time basis as of May 31, 1990 and on a full time basis as of June 7, 1990.

13. On July 25, 1990, the EPA approved the location of new off-site (to the south) monitoring well locations which were discussed during a previous Technical Review Committee meeting at BAAP.

14. On August 7, 1990, BAAP submitted a document entitled "Applicable or Relevant and Appropriate Requirements" to the WDNR.

15. On September 10, 1990, BAAP made a public announcement that metaTrace analytical data would not be used by the Army for completion of the RI/FS and that the RCRA corrective action process would be set back by approximately 20 to 24 months in order to resample soils and groundwater internal and external to the BAAP facility.

16. In October, 1990, BAAP submitted a document entitled "IRM Operation & Maintenance Manual (Operating Manual) - Groundwater Treatment Facility".

17. On October 10, 1990, BAAP submitted a letter addressing "Proposed IRP Soil Cutting, Sampling Analysis and Disposal. On November 23, 1990, BAAP sent another letter addressing additional WDNR concerns about "Management of Installation Restoration Program (IRP) Waste Soil Cuttings".

18. In December, 1990, BAAP submitted a "Draft Interim Remedial Measures Implementation Report". A "(Final) Interim Remedial Measures Implementation Report" was submitted to the WDNR on December 27, 1990.

19. On February 12, 1991, BAAP responded to EPA concerns about freeze protection for the IRM air stripper.

20. On February 25, 1991, the EPA forwarded a copy of a memo from the U.S. Army Toxic and Hazardous Materials Agency (USATHMA) proposing a revised RI/FS schedule.

21. On March 29, 1991, the WDNR issued BAAP a "Interim License Modification, Feasibility Plan of Operation Report Call In" letter for the Propellant Burning Grounds.

22. On April 3, 1991, BAAP sent WDNR a letter proposing a program for "Management of Installation Restoration Program (IRP) Waste Soil Cuttings.

23. On April 19, 1991, BAAP sent WDNR a document entitled "Findings-Badger Ordnance Works Excess Area 1940 - 1949" which includes aerial photos and photo interpretation of area along the eastern boundary of BAAP that are known as Formerly Used Defense Sites (FUDS) properties. This document provided the basis for proposed additional soil and groundwater investigations to the east of the BAAP facility.

24. In April, 1991, BAAP submitted a report entitled "Geophysical Investigation at an Existing Landfill" prepared by USATHMA.

25. In May, 1991, BAAP submitted a report entitled "Badger AAP On-Site Wells" which presented boring logs, well construction reports and survey location data for some, but not all monitoring wells being monitored at the BAAP facility.

26. On May 9, 1991, USATHMA submitted a request for waiver (for construction) for alternative construction of 10 piezometers to be located on the east side of the BAAP facility. On May 15, 1991, the WDNR approved an alternative monitoring well construction waiver for 3 on-site and 7 off-site piezometers.

27. On May 20, 1991, BAAP submitted a document entitled WPDES Permit No. WI-0046566-1/In-Field Conditions Approval: Receiving Water Biological Study No. 32-24-0025-91".

28. On June 3, 1991, June 24, 1991, July 18, 1991, August 15, 1991, and submitted documents providing pumpage totals and elevations for the IRM treatment system extraction wells.

29. On July 3, 1991, the EPA sent BAAP a letter about "Inspection to Determine Compliance With Land Disposal Restrictions". EPA determined that BAAP was in compliance with the EPA Land Disposal Restrictions.

30. On July 29, 1991, BAAP forwarded (to WDNR) a copy of groundwater flow modeling efforts performed by ABB.

31. On July 31, 1991, the Corps of Engineers (COE) FAX'd a copy of "Monitoring Well Installation Plan for BAAP (FUDS project)".

32. On August 2, 1991, the COE FAX'd a copy of "Sampling and Analysis Work Statement (for FUDS site)".

33. On August 14, 1991, the EPA approved the locations of proposed (by BAAP) off-site (to the south) new monitoring well locations.

34. In August, 1991, BAAP submitted a document entitled "Summary of Responses to Comments on Draft Sampling Design Plan Addendum by: COE, USAEHA; on FAX DRAFT comments by: WDNR/EPA; on WRITTEN FORMAL comments by: WDNR/EPA. An errata sheet for the Draft Sampling and Design Plan Addendum was submitted by ABB to USATHMA on August 22, 1991.

35. In August, 1991, BAAP submitted the following reports:

- RI/FS Draft Health and Safety Plan Addendum
- RI/FS Draft Quality Control Plan Addendum
- RI/FS Draft Sampling and Design Plan Addendum

36. On September 4, 1991, the EPA provided BAAP and ABB written comments about ABB's proposal for resampling soil and groundwater for the RI/FS.

37. On September 13, 1991, the EPA approved the Draft Sampling Design Plan Addendum submitted by BAAP/ABB.

38. On September 23, 1991, the EPA approved the Draft Health and Safety Plan Addendum submitted by BAAP/ABB.

39. In October, 1991, BAAP submitted documents entitled "RI/FS Draft Final Health and Safety Plan Addendum", "RI/FS Draft Final Sampling Design Plan Addendum" and "Draft Final Quality Control Plan Addendum".

40. On October 9, 1991, BAAP submitted copies of "Draft Final Sampling Design Plan Addendum" and "Draft Final Health and Safety Plan Addendum".

41. On October 28, 1991, BAAP's consultant, ABB, contacted the WDNR for permission to perform a hydraulic pump test on the IRM system to re-assess the aquifer characteristics and to re-evaluate the performance of the IRM system. A plan approval modification to temporarily shut down the IRM system to prepare for this pump test was issued by the WDNR on October 31, 1991. On November 11, 1991, the WDNR Private Water Supply section gave approval to perform a pump test at a pumping rate of up to 200 gallons per minute.

42. On November 22, 1991, the EPA provided comments to BAAP about the Draft Final Quality Control Plan Addendum and Draft Final Health and Safety Plan Addendum. EPA and WDNR comments on these documents were forwarded to BAAP on September 13, 1991 and September 23, 1991 - all EPA/WDNR comments were addressed satisfactorily by BAAP.

43. On November 11, 1991, the EPA provided BAAP with review comments on the following documents:

- Draft Final Quality Control Plan Addendum
- Draft Final Sampling Design Plan Addendum
- Draft Final Health and Safety Plan Addendum

44. On November 22, 1991 the U.S. EPA approved the documents identified in Finding of Fact 43.

45. BAAP submitted the following electronic groundwater data on the associated dates:

Sampling Quarter	TAD Submittal Date
March 1990	November 21, 1991
June 1990	December 19, 1991
September 1990	January 14, 1992
December 1990	January 20, 1992
March 1991	January 23, 1992
June 1991	January 30, 1992
September 1991	February 24, 1992
December 1991	March 5, 1992
June 1988	May 14, 1992
September 1988	May 14, 1992
June 1989	April 29, 1992
September 1989	April 29, 1992

46. On November 26, 1991, BAAP/ABB submitted hard copy and diskettes for groundwater monitoring results for March 1990 to the WDNR.

47. On December 23, 1991, BAAP submitted a request to temporarily suspend General Condition No. 10 of the September 14, 1987 WDNR approval which requires BAAP to submit a narrative summary of quarterly monitoring results. The WDNR approved this request on December 27, 1991.

48. In December, 1991, BAAP submitted the following reports:

- RI/FS Final Sampling Design Plan Addendum
- RI/FS Final Health and Safety Plan Addendum
- RI/FS Final Quality Control Plan Addendum

49. On September 17, 1992, Mid-State Associates, Inc. submitted a report entitled "Staff Guage Location - Horizontal & Vertical" on behalf of BAAP.

50. On March 19, 1992, the WDNR issued a plan approval modification to BAAP that required the submission of a report that analyzes and discusses the details of an aquifer pump test performed at the facility in December, 1991.

51. On March 30, 1992 BAAP submitted a "Feasibility/Plan of Operation Report for an Open Burning Thermal Treatment Unit".

52. On June 2, 1992, ABB submitted a copy of a "Draft Aquifer Pumping Test Report" as required by the Department's March 19, 1992 plan approval modification.

53. The contaminants carbon tetrachloride and trichloroethylene continue to leave the site on the south side of the facility at levels that exceed the Enforcement Standards established under s. NR 140.10, Wis. Adm. Code.

54. The Interim Remedial Measures system is inadequate for preventing the migration of contaminants (carbon tetrachloride, trichloroethylene and others) off of the BAAP facility. Carbon tetrachloride and trichloroethylene levels that are above the Enforcement Standards established in s. NR 140. 10, Wis. Adm. Code have been detected below the bottom of the extraction well screens and down gradient of (to the south) the Interim Remedial Measures system.

55. Other documents considered in connection with this plan approval modification include:

    a. Groundwater monitoring files held at the Department of Natural Resources office.

    b. General correspondence files about groundwater quality.

56. On September 14, 1992 the Department issued a Notification of Intent to Modify a Plan Approval, Badger Army Ammunition Plant letter that contained, as an attachment, a Draft "Plan Modification of the September 14, 1987 In - Field Conditions Report Approval".

57. On October 19, 1992 the Department received a letter from the Department of the Army that contained comments about the draft plan approval modification identified in Finding of Fact 56.

58. On October __, 1992 the Department formally responded to the U.S. Army comments identified in Finding of Fact 57.

CONCLUSIONS OF LAW

1. The WDNR has authority under Subchapter IV of Ch. 144, Stats., and Ch. NR 508, Wis. Adm. Code, to approve an in-field conditions report with special conditions if the conditions are needed to ensure compliance with Ch. 144, Stats., and Chs. NR 500 through 520 and Chs. NR 600 through 685, Wis. Adm. Codes.

2. The conditions of approval set forth below are needed to ensure compliance with ch. NR 504.04, Wis. Adm. Code, Chs. NR 600 through NR 685 and ch. NR 140.20, Wis. Adm. Codes.

3. In accordance with the foregoing, the WDNR has authority under s. 144.44, Stats., to issue the following plan modification to the September 14, 1987 In-Field Conditions Report approval.

CONDITIONAL MODIFICATION TO THE SEPTEMBER 14, 1987 IN-FIELD CONDITIONS REPORT

Based on the foregoing Findings of Fact and Conclusions of Law, the Department hereby approves the documents listed in Findings of Fact Nos. 14, 18, and 46 subject to compliance with Chs. NR 140, NR 500 - 520 and NR 600 - 685, Wisconsin Administrative Code and the following conditions:

Schedule

1. The revised schedule for completion of investigation, evaluation and implementation of corrective measures activities as proposed by the USATHMA on February 20, 1991 and contained in Finding of Fact (FOF) 20 is unacceptable and has been modified. The schedule below supersedes Condition 1 of the WDNR February 21, 1991 approval. A starting date of December 31, 1992 will be used for all remaining corrective action activities. The remainder of the corrective action schedule from that date forward incorporates the same tasks and goals required by the October 30, 1988 EPA permit and incorporates the conditions of the November 21, 1991 WDNR plan approval modification in order to merge the time frames of the two documents and to avoid future confusion. Furthermore, the schedule contains modified dates of accomplishment to reflect the time lost as a result of the loss of the metaTrace data and subsequent resampling efforts now being performed by BAAP. Note that time periods are used as well as specific dates for individual tasks.

   The primary date that BAAP must comply with is the date listed for each particular task. The time period (eg., "120 days") should only be used by BAAP as a guide for planning purposes or if the scheduled dates need to be adjusted. The "Tasks" referred to in the schedule are equivalent to Tasks in the October 30, 1988 EPA Permit. If either the U.S. Army, the U.S. EPA or the Department cannot meet a completion date or review deadline and if such delays affect the overall schedule, the Department may, upon submittal of justification and notification of the need for the delay, move the completion date requirements backward in one month increments.

Deliverable		Due Date
a.	Submit the Draft RFI Report. This corresponds to "Phase I RI Interim Report" - 02/22/91 WDNR Approval.	Dec. 31, 1992
b.	WDNR review - 30 days.	January 31, 1993
c.	Submit the Final RFI Report (Tasks IV and V) within 60 days after receipt of WDNR comments on the Draft RFI Report. This corresponds to "Final Phase I and II RI Report" - 02/22/91 WDNR Approval.	March 31, 1993
d.	WDNR review - 30 days.	April 30, 1993
e.	Submit the Draft Corrective Measures Study Report (Task XI) which includes the Identification and Development of the Corrective Measure Alternative(s) Report (Task VIII), the Evaluation of the Corrective Measure Alternatives (Task IX) and Justification and Recommendation of the Corrective Measure(s) within 90 days after receipt of WDNR written coments on the Final RFI Report. This corresponds to "FS Draft Report" - 02/22/91 WDNR Approval.	June 30, 1993
f.	WDNR review - 30 days.	July 31, 1993
g.	Submit Final Corrective Measure(s) Study (Task XI) within 60 days after receipt of WDNR comments on the Draft CMS report. This corresponds to "FS Final Report" - 02/22/91 WDNR Approval.	Sept. 30, 1993
h.	WDNR review - 30 days.	Oct. 30, 1993
i.	Public Participation Period and EPA/WDNR approval of selected Corrective Measure(s) - The WDNR will allow up to 60 days for public comment. WDNR and EPA will jointly notify BAAP of the approved corrective measure(s), if any. This corresponds to "Public Meeting" and "Final ROD" - 02/22/1991 WDNR Approval.	Dec. 31, 1994

Corrective Measures Implementation

j.	Submit a Draft Program Plan (Task XII) within 30 days after receipt of written notification by WDNR and EPA of the Corrective Measure(s) to be implemented at BAAP. This requirement has no previous WDNR approval equivalent.	February 28, 1994
k.	WDNR review - 30 days.	March 31, 1994
l.	Submit a Final Program Plan within 30 days after receipt of WDNR written comments. This requirement has no previous WDNR approval equivalent.	April 30, 1994

m. Submit the following Design and Construction Reports:

(1)	Preliminary Design (30% complete) (Task XIIIG.1.) within 90 days after submittal of the Final Program Plan. This requirement has no previous WDNR approval equivalent.	July 31, 1994
(2)	Intermediate Design (60% complete) (Task XIIIG.2.) within 90 days after submittal of the Preliminary Design (180 days after submitting Final Program Plan). This requirement has no previous WDNR approval equivalent.	October 31 , 1994
(3)	Prefinal Design (Draft Plans)(Task XIIIG.6.) within 90 days after submittal of the Intermediate Design (270 days after submitting Final Program Plan). This requirement has no previous WDNR approval equivalent.	January 31, 1994
(4)	WDNR review - 30 days.	March 31, 1995
(5)	Draft Design Plans and Specs (Task XIIIG.6.) within 60 days after receiving WDNR comments on Prefinal Design (Draft Plans). This requirement has no previous WDNR approval equivalent.	May 31, 1995
(6)	WDNR review - 30 days.	June 30, 1995
(7)	Draft Construction Quality Assurance (CQA) Plan (Task XIV) within 30 days after receiving WDNR comments on Draft	July 31, 1995

Design Plans and Specs. This requirement has no previous WDNR approval equivalent.

(8)	WDNR review - 30 days.	August 31, 1995
(9)	Final CQA Plan within 30 days after receiving WDNR comments on Draft CQA Plan. This requirement has no previous WDNR approval equivalent.	Sept. 30, 1995

Construction

n.	Commence construction of corrective measures. This corresponds to "Design/Implementation" - 02/22/91 WDNR Approval.	October 31, 1995
o.	Conduct Pre-Final Inspection (Task XIV) within 120 days after start of construction or when CMI is 50% complete. This requirement has no previous WDNR approval equivalent.	February 28, 1995
p.	Submit Pre-Final Inspection Report (Task XIV) within 30 days after the pre-final inspection. This requirement has no previous WDNR approval equivalent.	March 31, 1996
q.	Complete construction within 90 days after submission of Pre-Final Inspection Report or 240 days after start of construction. This requirement has no previous WDNR approval equivalent.	June 30, 1996
r.	Submit Draft CMI Report (Task XV) within 30 days after completion of construction. This requirement has no previous WDNR approval equivalent.	July 31, 1996
s.	WDNR review - 30 days.	August 31, 1996
t.	Submit Final CMI Report (Task XV) within 30 days after receiving written comments on Draft CMI Report. This requirement has no previous WDNR approval equivalent.	Sept. 30, 1996

Operation and Maintenance Progress Reports

u. BAAP shall submit Operation and Maintenance Progress Reports semiannually by :o later than January 15 and July 15 of each year

the corrective measure(s) is (are) in operation.

2. The report submitted by BAAP in May, 1991 (Finding of Fact 25) does not contain finalized boring logs and well construction forms for many borings and wells - they are hand written forms that were generated in the field, have not been subjected to a quality assurance program review and therefore will be considered incomplete until they are finalized. In accordance with s. NR 141.23, Wis. Adm. Code, all missing or new boring logs shall be submitted to the WDNR by no later than 60 days from the date of this plan approval modification. Finalized boring logs shall be submitted to the Department within six (6) months from the date of this plan approval modification. Please note that the WDNR does not expect BAAP to re-submit the entire document listed in FOF 23. We are only requiring that BAAP submit the missing or incomplete boring logs and well construction forms from that document. The WDNR will add the missing information to the document BAAP previously submitted.

   Date Complied With (WDNR use only) ____________________

INTERIM REMEDIAL MEASURES

3. The construction documentation report for the IRM system is hereby approved.

4. Groundwater contaminant isoconcentration contours in a cross-section through the propellant burning ground area clearly indicate that the existing extraction wells for the IRM system are not deep enough to fully intercept the contaminant plume. The plume is below the bottom of the extraction wells. Although the Department has not completed its review of the pump test performed by ABB in December, 1991, our preliminary analysis of the pump test indicates that the extraction wells are not deep enough and that the currently approved pumping rates are too low. In fact, the summary section (§ 7.0) of the "Draft Aquifer Pumping Test Report" submitted by ABB on BAAP's behalf states that the efficiency of well BCW-3 is low and this may be due to improper well installation, development or biological plugging of the well screen. Therefore, BAAP shall evaluate the entire IRM system including the extraction wells and treatment system and submit a report to the Department within 90 days of the date of this approval that includes the following:

   a. The relationship (in cross-section) and discussion of the spatial distribution of all the major contaminants of concern to the physical location of the screened areas of the extraction wells.

   b. A proposal for evaluating the efficiency of each of the existing extraction wells.

c. An evaluation of the existing extraction wells to determine which design parameters need to be modified in order to achieve a more efficient contaminant extraction rate.

d. A program for future inspection and reporting of extraction well efficiencies to determine if biological clogging or iron encrusting is reducing the efficiency of the extraction well screens. This program shall also propose remedies for unclogging or unplugging extraction well screens.

e. An evaluation of the need for installing deeper extraction wells and the need for additional extraction wells. Recommendations for how deep and what number of additional extraction wells shall also be included.

f. An evaluation of the pump sizes currently being used in the IRM system and recommendations, if appropriate, for increasing the sizes of the pumps and associated pumping rates for the extraction system.

g. An evaluation of the existing treatment system and any modifications that may be needed if the evaluation of the extraction wells, pump sizes and pumping rates indicate that the overall extraction system needs to be upgraded.

h. A proposed time table for implementing any upgrades to the IRM system.

i. A summary of any and all required existing permits that would be required if the analysis shows that the IRM system needs to be upgraded.

Date Complied With (WDNR use only) ____________________

ENVIRONMENTAL MONITORING

Area A - Propellant Burning Grounds: Lic.# 02813, FID #157005530

5. The vertical and horizontal extent of contamination still has not been properly defined. Therefore, BAAP shall install new well nests in the area downgradient from the propellant burning ground site at the following approximate locations and depths:

- C Well at PBM 8906 - drilling can proceed without sampling to a depth

equivalent to the bottom of the bore hole at PBM 8906. Thereafter, soils shall be logged at five (5) foot intervals and classified according to the Unified Soil Classification System (USCS).

- B & C wells at grid coordinates 489,250 N: 2,068,000 E
- B & C wells at grid coordinates 489,250 N: 2,068,500 E
- B, C & D wells at grid coordinates 487,000 N: 2,065,000 E
- B, C & D wells at grid coordinates 487,000 N: 2,068,000 E
- B, C & D wells at grid coordinates 487,000 N: 2,068,500 E
- B, C & D wells at grid coordinates 486,250 N: 2,065,000 E
- B, C & D wells at grid coordinates 486,250 N: 2,068,500 E

Notes:

a. "B" wells shall be screened in the gravel layer typically found between elevations 700 and 725 feet MSL.

b. "C" wells shall be screened in the thick sequence underlying the gravel zone of the "B" well placement.

c. "D" wells shall be screened in the second gravel layer encountered just above bedrock.

All new wells shall be installed and developed in time to be included in the March, 1992 sampling event.

6. Beginning with the December, 1992 sampling quarter, BAAP shall monitor the Propellant Burning Grounds According to the following schedule (except for new well installations which must be included in the March, 1993 sampling period):

<u>Wells</u>

PBN 8201 A,B,C	PBN 8202 A,B,C
PBN 8203 A,B,C	PBN 8204 A,B,C
PBN 8205 A,B,C	PBM 8506
PBN 8501 A	PBN 8502 A
PBN 8503 A	PBN 8504 A
PBM 8906	PBN 8901 B,C,D
PBN 8902 B,C	PBN 8903 C
PBN 8904 B,C	PBN 8910 A,B,C,D
PBN 8912 A,B	LON 8902 A,B

LON 8903 A,B	PBN 9106 C,D
PBN 9112 C,D	BGM 9101
BGM 9102	BGM 9103
LOM 9102	PBM 8204
PBN 8903 B	All new wells required in Condition 5.

Parameters and Monitoring Frequency

Quarterly Monitoring	**Annual Monitoring**
pH	-VOC's and Semi-volatiles *
Specific Conductance	-Metals (filtered) *
Nitrate Nitrogen	* See Condition 35
Carbon Tetrachloride	
Chloroform	
Trichloroethylene	
1,1,1 Trichloroethylene	

Area B - Deterrent Burrning Grounds: Lic. #03037, FID #15706760

7. Beginning with the December, 1992 sampling period, BAAP shall monitor the Deterrent Burning Grounds according to the following schedule:

Wells

DBN 8904 A,B
DBN 8201 B,C
S 1122
DBM 8905

Parameters and Monitoring Frequency

Quarterly Monitoring	**Annual Monitoring**
pH	- VOC's and Semi-volatiles *
Specific Conductance	- Metals *
Sulfate	* See Condition 35
Nitrate Nitrogen	
Chromium (filtered)	

Area C - Existing Landfill: Lic. # 02813, FID #157005530

8. Beginning with the December, 1992 sampling period, BAAP shall monitor the Existing Landfill (also referred to as the "Formerly Existing Landfill") according to the following schedule:

Wells

ELN 8201 A,B & C
ELN 8203 A,B & C
ELM 8901
ELM 8903
ELM 8905
ELM 8907
ELM 8908
ELN 8902 A & B
ELN 8904 A & B
ELN 9107 A & B
ELM 9110
S 1134
S 1135

Parameters and Monitoring Frequency

Quarterly Monitoring

pH
Specific Conductance
Hardness
Alkalinity
Chloride
Dissolved Iron
Sulfate
Manganese
Chromium (Dissolved)
Lead (Dissolved)
Mercury (Dissolved)
Nitrate Nitrogen
Total Dissolved Solids

Annual Monitoring

-VOC's and Semi-volatiles *
-Metals *
* See Condition 35

Area D - Southern Perimeter/Settling Ponds: Lic. #03499/FID #157005530

9. Beginning with the December, 1992 sampling period, BAAP shall monitor the Southern Perimeter/Settling Pond area according to the following schedule:

Wells

S 1101
S 1102
S 1103
S 1104
S 1105
S 1106
S 1107
S 1108
S 1133
S 1152 A
S 1152 B
SPN 8901 C
SPN 8902 A,B & C
SPN 8903 B & C
SPN 8904 B & C
SPN 8905 A & B
SPN 9102 D
SPN 9103 D

S 1147	SPN 9104 D
S 1148	S 1149

Parameters and Monitoring Frequency

Quarterly Monitoring	**Annual Monitoring**
pH	- VOC's and Semi-volatiles *
Specific Conductance	- Metals *
Nitrate Nitrogen	* See Condition 35
Carbon Tetrachloride	
Trichloroethylene	
Chloroform	
Benzene	
Chromium (filtered)	

Area E - Oleum Plant and Pond: Lic. #03495, FID #157005530

10. Beginning with the December, 1992 sampling period BAAP shall monitor the Oleum Plant and Pond area according to the following schedule:

Wells

S 1132
OPM 8901
OPM 8903

Monitoring Parameters and Frequency

Quarterly Monitoring	**Annual Monitoring**
pH	- VOC's and Semi-volatiles *
Specific Conductance	- Metals *
Sulfate	* See Condition 35
Chloride	

Area E - Ballistics Pond: Lic. #03483, FID #157005530

11. Beginning with the December, 1992 sampling period, BAAP shall monitor the Ballistics Pond according to the following schedule:

Wells

S 1127

Monitoring Parameters and Frequency

VOC's and Semi-volatiles - Annually *

Metals - Annually *

* See Condition 35

Area E - Old Acid Area and Fuel Tank: Lic. #03481, FID #157005530

12. Beginning with the December, 1992 sampling period BAAP shall monitor the Old Acid Area and Fuel Tank according to the following schedule:

<u>Wells</u>

S 1126
OAM 8901
OAM 8902
OAM 9101
FTM 8901

<u>Monitoring Parameters and Frequency</u>

Quarterly Monitoring	**Annual Monitoring**
pH	- VOC's and Semi-volatiles *
Specific Conductance	- Metals *
Nitrate Nitrogen	* See Condition 35
Benzene (FTM 8901 only)	
Trichloroethylene (FTM 8901 only)*	
Methylene Chloride*	

* The need for further sampling for this parameter will be re-evaluated after four sampling events beginning with the December, 1992 sampling event. If no detects are found, these parameters may be deleted from the sampling program.

Area E - Magazine Area: Lic. #03491, FID #157005530

13. Beginning with the December, 1992 sampling period, BAAP shall monitor the Magazine area according to the following schedule:

<u>Wells</u>

S 1116

Monitoring Parameters and Frequency

VOC's and Semi-volatiles - Annually *

Metals - Annually *

* See Condition 35

Area E - Nitroglycerine Pond/Rocket Paste Area: Lic. #03487, FID #157005530

14. Beginning with the December, 1992 sampling period, BAAP shall monitor the Nitroglycerine Pond/Rocket Past Area according to the following schedule:

Wells

S 1124	S 1125
S 1118	S 1119
S 1150	NPM 8901
RPM 8901	RPM 8902
RPM 9101	

Monitoring Parameters and Frequency

Quarterly Monitoring	Annual Monitoring
pH	- VOC's and Semi-volatiles *
Specific Conductance	- Metals *
Nitrate Nitrogen	* See Condition 35

Area E - Southeast Boundary: Lic.#03038, FID # 157065370

15. Beginning with the September, 1992 sampling period BAAP shall monitor the Southeast Boundary wells according to the following schedule:

Wells

S 1111
S 1112
S 1113
S 1114

Monitoring Parameters and Frequency

Quarterly Monitoring	Annual Monitoring

Nitrate Nitrogen	- VOC's and Semi-volatiles *
	- Metals *
	* See Condition 35

Area F - New Acid Area: Lic. #02934, FID #157065150

16. Beginning with the December, 1992 sampling period BAAP shall monitor the New Acid area according to the following schedule:

<u>Wells</u>

NAN 8101 A & D
NAN 8102 B
NAN 8103 B & C
NAN 8104 B & C

<u>Monitoring Parameters and Frequency</u>

Quarterly Monitoring	Annual Monitoring
pH	- VOC's and Semi-volatiles *
Specific Conductance	- Metals *
Nitrate Nitrogen	* See Condtion 35
Sulfate	

Area G - Offsite Plume Wells

17. Beginning with the December, 1992 sampling period BAAP shall monitor the Offsite Plume wells according to the following schedule:

<u>Wells</u>

SWN 9101 B,C & D	SWN 9102 C & D
SWN 9103 B,C,D & E	SWN 9104 C & D
PBN 9101 C	PBM 9001 D
PBM 9002 D	PBN 9102 B & C
PBM 9003 D	PBN 9103 B & C
PBN 9004 B & D	SWN 9105 B, C & D

<u>Monitoring Parameters and Frequency</u>

VOC's and Semi-volatiles - Quarterly *
Metals - Quarterly *
* See Condition 35

Area H - New Landfill: Lic. #03118, FID# 15707420

18. Beginning with the September, 1992 sampling period BAAP shall monitor the New Landfill wells according to the following schedule:

    Wells

    NLN 8201 A,B,C
    NLN 8202 A,B,C
    NLN 8203 A,B,C
    NLN 8204 A,B,C
    NLN 8205 B,C
    NLN 9205 A
    NLN 9202 R
    Collection Lysimeter

    Monitoring Parameters and Frequency

    All existing parameters required by WDNR Solid Waste Section Approval - Quarterly

    VOC's and Semi-volatiles - Annually *

    Metals - Annually *

    Collection Lysimeter - VOC's and Semi - volatiles *, metals *, Total Dissolved Solids and Nitrate Nitrogen - Annually

    * See Condition 35

Private Well Monitoring

19. Private well monitoring requirements for Premo, Spears, Schaeffer and Graf remain unchanged except that private well water quality samples shall not be filtered prior to being analyzed.

GENERAL

20. Within 120 days of the date of this approval, BAAP shall submit a summary of all past investigations that have occurred in the Grubers Grove area. The summary shall include a status of decisions made by investigators or agencies involved in producing any reports or decisions. BAAP should be aware that the Hazardous Waste Section has been notified by our Water Resources Management section that the Lower Wisconsin River Water Quality Management Plan will re-open the investigation of contaminated sediments in Grubers Grove. We are not, at this time requiring any immediate evaluation of the contaminated sediments in Grubers Grove but the summaries required herein will

provide a starting point if such an evaluation should be needed.

Date Complied With (WDNR use only)______________________

21. This plan approval modification provides for a substantial reduction in the number of monitoring wells that BAAP has been sampling. However, BAAP shall not abandon any of the wells that no longer require monitoring as a result of this approval. All monitoring wells that are not included in the monitoring program required by this approval shall be considered to be in a standby status. All such monitoring wells shall be physically evaluated on a yearly basis, in June, and the results of the evaluation reported to the department along with the annual groundwater quality monitoring results. BAAP shall continue to measure water levels in each standby monitoring well on a quarterly basis during the months of March, June, September and December of each year. The results of water level monitoring shall be reported to the Department along with the annual report required by Condition 27 of this plan approval modification. Each monitoring well shall be evaluated for depth (by measurement), siltation (by measurement), frost heave and damage. If measurements note that more than six (6) inches of silt or other debris has accumulated in the bottom of any monitoring well, that well shall be rehabilitated by development or flushing within 60 days of discovery of the siltation problem. A report of the success or failure of the rehabilitation efforts shall be provided to the Department within 30 days after the effort was made. Any well that cannot be rehabilitated or that is damaged shall be replaced within 60 days of discovery of the problem.

22. BAAP shall properly abandon and replace with a deeper well any existing monitoring well that has historically been dry.

23. BAAP shall prepare and submit for review a detailed groundwater flow map utilizing water levels from water table observation wells or wells that have screens in close proximity (within approximately 10 feet) of the water table. This map shall include "tie ins" to the elevations of at least two surface water staff gauges placed in Lake Wisconsin on the east side of the facility.

24. BAAP shall sample any new wells installed on or off of the facility property for the hazardous substance list organics and hazardous substance list metals (filtered) and nitrate nitrogen immediately upon proper completion and development of the well. All new wells constructed on or off of the facility by either BAAP or any other agency or contractor under the direction of or under contract to BAAP, the Department of the Army, the Corps of Engineers or the Department of Defense shall be installed, completed, developed, and reported in accordance with the requirements of ch. NR 141, Wis. Adm. Code. Completed boring logs and well construction reports with horizontal and

vertical survey information shall be submitted to the department within 60 days of the well being drilled.

25. Groundwater samples collected from monitoring wells shall be field filtered using a 0.45 micron filter for metals analysis.

26. Water samples from private residences shall not be filtered for metals analysis.

27. The narrative summary of all inorganic and organic water quality results required quarterly by Condition 10 of the September 14, 1987 In-Field Conditions Report approval is hereby changed to an annual requirement to be submitted to the Department on or before June 1 of each year. Each annual summary shall discuss groundwater quality trends as indicated by monitoring results from the previous year's March, June, September, and December sampling periods. All other requirements contained in Condition 10 of the September 14, 1987 approval remain the same.

28. All quarterly groundwater monitoring sampling events shall take place within 20 days of March 15, June 15, September 15, and December 15 of each year.

29. All annual groundwater monitoring sampling events shall take place within 20 days of June 15th of each year.

30. All groundwater monitoring results shall be submitted to the Department within 60 days after the sample(s) has been taken.

31. All groundwater monitoring results shall be submitted to the Department electronically.

32. The analytical methods used for all groundwater quality analyses shall be equivalent to U.S. EPA methods 8021, 8260, 8010/8020 or 8240 (8021 or 8260 are preferred) for volatile organic compounds and U.S. EPA method 8250 or 8270 for semi-volatiles.

33. As required by s. NR 140.16, Wis. Adm. Code, BAAP shall utilize the lowest detection limit possible for analyzing groundwater samples. Where no analytical methodology is specified (in NR 140) BAAP shall use an analytical methodology with a detection limit and limit of quantitation below the preventive action limit. Where the limit of detection or limit of quantitation is above the preventive action limit for a substance, BAAP shall use the best available analytical methodology to produce the lowest limit of detection and limit of quantitation. In all cases, the <u>lowest</u> limit of detection shall be used.

34. BAAP shall properly abandon monitoring wells NAN 8103 A and NAN 8104 A in accordance with the procedures outlined in Ch. NR 141, Wis. Adm. Code within 60 days of this approval.

35. The Volatile Organic Compounds (VOC's) and Semi-volatiles referred to in monitoring programs contained herein shall be consistent with BAAPS <u>existing</u> groundwater monitoring parameter list. Metals shall include Arsenic, Barium, Cadmium, Chromium, Lead, Mercury, Selenium, Silver and Zinc. All monitoring well samples for metals shall be field filtered.

The Department retains the right to require the submittal of additional information and to further modify conditional approvals at any time if, in the Departments opinion, further modifications are necessary. Unless specifically noted, the conditions of this approval do not supersede or replace any previous conditions of approval for this facility.

NOTIFICATION OF APPEAL RIGHTS

If you believe that you have a right to challenge this decision, you should know that Wisconsin statutes and administrative rules establish time periods within which requests to review Department decisions must be filed.

For judicial review of a decision pursuant to sections 227.52 and 227.53, Stats., you have 30 days after the decision is mailed, or otherwise served by the Department, to file you petition with the appropriate circuit court and serve the petition on the Department. Such a petition for judicial review shall name the Department of Natural Resources as the respondent.

This notice is provided pursuant to section 227.48(2), Stats.

Dated:

Barbara Zellmer /LS

Barbara Zellmer, Chief
Hazardous Waste Management Section
Bureau of Solid & Hazardous Waste

Lakshmi Sridharan

Lakshmi Sridharan, Chief
Solid Waste Management Section
Bureau of Solid & Hazardous Waste

Mike Netzer

Mike Netzer, Hydrogeologist
Hazardous Waste Management Section
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Janet DiMaggio

Janet DiMaggio, Hydrogeologist
Solid Waste Management Section
Bureau of Solid & Hazardous Waste

Martin J. Herrick MJH

Martin J. Herrick, Engineer
Hazardous Waste Management Section
Bureau of Solid & Hazardous Waste

cc: Bob Egan, U.S. EPA Region V, 5HRP - 8J
Jim McKenna, USATHAMA

a:BAAP25.mjn

APPENDIX D.2

COSTS: SOIL ALTERNATIVES

PROPELLANT BURNING GROUND

DATE: 03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION SS-1 MINIMAL ACTION
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

JOB # 6853-09

ESTIMATOR: P. R. MARTIN

OPTION SS-1 MINIMAL ACTION COST SUMMARY TABLE DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
DIRECT COST OF OPTION SS-1 MINIMAL ACTION				
INSTITUTIONAL CONTROLS				$10,000
FENCING & WARNING SIGNS				74,000
TOTAL DIRECT COST OF OPTION SS-1 MINIMAL ACTION				$84,000
INDIRECT COST OF OPTION SS-1 MINIMAL ACTION				
HEALTH AND SAFETY			5.00%	$4,000
LEGAL, ADMIN, PERMITTING			5.00%	4,000
ENGINEERING			10.00%	8,000
SERVICES DURING CONSTRUCTION			10.00%	8,000
TOTAL INDIRECT COST OF OPTION SS-1 MINIMAL ACTION				$24,000
TOTAL CAPITAL (DIRECT + INDIRECT) COST				$108,000
OPERATING AND MAINTENANCE COSTS				
TOTAL ANNUAL OPERATING AND MAINTENANCE COSTS				$11,000
TOTAL PRESENT WORTH OF ANNUAL O&M COSTS (5% FOR THIRTY YEARS)				$169,000
TOTAL PRESENT WORTH OF OPERATING AND MAINTENANCE COSTS				$169,000
TOTAL COST OF OPTION SS-1 MINIMAL ACTION				$277,000

DATE: 03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION SS-1 MINIMAL ACTION
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

JOB # 6853-09

ESTIMATOR: P. R. MARTIN

OPTION SS-1 MINIMAL ACTION

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
INSTITUTIONAL CONTROLS	1	LS	10000.00	$10,000
FENCE & WARNING SIGNS				
FENCE	4400	LF	12.50	$55,000
GATE	2	EA	900.00	1,800
WARNING SIGNS	89	EA	50.00	4,450
CONTINGENCY ~20%				12,750
TOTAL FENCE & WARNING SIGNS				$74,000
ANNUAL OPERATING & MAINTENANCE COSTS				
EDUCATIONAL PROGRAMS	1	LS	5000.00	$5,000
FENCE & WARNING SIGNS	5.00%	LS	61250.00	3,063
FIVE YEAR SITE REVIEW @ $10,000 EVERY FIVE YEARS	1	LS	1809.75	1,810
CONTINGENCY ~10%				1,128
TOTAL ANNUAL OPERATING & MAINTENANCE COSTS				$11,000

DATE: 03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION SS-2 SOIL COVER

JOB # 6853-09

LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT

ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SS-2 SOIL COVER COST SUMMARY TABLE DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
DIRECT COST OF OPTION SS-2 SOIL COVER				
SITE PREPARATION AND MOB/DEMOB				$235,000
CONTAMINATED SOIL DELINEATION				147,000
SOIL COVER				667,000
SURFACE WATER MANAGEMENT				6,000
INSTITUTIONAL CONTROLS				10,000
TOTAL DIRECT COST OF OPTION SS-2 SOIL COVER				$1,065,000
INDIRECT COST OF OPTION SS-2 SOIL COVER				
HEALTH AND SAFETY			5.00%	$53,000
LEGAL, ADMIN, PERMITTING			5.00%	53,000
ENGINEERING			10.00%	107,000
SERVICES DURING CONSTRUCTION			10.00%	107,000
TOTAL INDIRECT COST OF OPTION SS-2 SOIL COVER				$320,000
TOTAL CAPITAL (DIRECT + INDIRECT) COST				$1,385,000
OPERATING AND MAINTENANCE COSTS				
TOTAL ANNUAL POST CLOSURE MAINTENANCE COSTS				$39,000
TOTAL PRESENT WORTH OF O&M COSTS (5% FOR THIRTY YEARS)				$600,000
TOTAL COST OF OPTION SS-2 SOIL COVER				$1,985,000

DATE: 03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SS-2 SOIL COVER
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SS-2 SOIL COVER SITE PREPARATION AND MOB/DEMOB DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
EQUIPMENT (IN OR OUT)				
FRONT END LOADER	2	EA	520.00	$1,040
DUMP TRUCKS	4	EA	260.00	1,040
BACKHOE	4	EA	520.00	2,080
DOZER	4	EA	1000.00	4,000
OFFICE TRAILER	3	MON	155.00	465
STORAGE TRAILER (2 EA)	6	MON	155.00	930
TRAILER SET-UP & DELIVERY, REMOVAL	3	EA	310.00	930
TOILET (2 EA*3 MON/EA*4.2 WK/MON)	25	WK	25.00	625
WATER CLR (2EA*3MON/EA*4.2WK/MON)	25	WK	25.00	625
WATER (25 WK * 5 DAY/WK)	125	DAY	15.00	1,875
TELEPHONE SERVICE	3	MON	520.00	1,560
ELECTRICAL HOOK-UP	1	LS	2500.00	2,500
ELECTRICAL POWER	3	MON	300.00	900
PICK-UP (2 EA * 3 MON/EA)	6	MON	1035.00	6,210
OFFICE EQUIPMENT	3	MON	1035.00	3,105
PUMPS, TOOLS MINOR EQUIPMENT	1	LS	5000.00	5,000
STOCKPILE AREA				
CLEAR & GRUB LIGHT VEGETATION	2	AC	3825.00	7,650
GRADE	3300	CY	2.00	6,600
GRAVEL - 12" THICK	9680	SY	3.50	33,880
PARKING AREA				
CLEAR & GRUB LIGHT VEGETATION	0.5	AC	3825.00	1,913
GRADE	825	CY	2.00	1,650
GRAVEL - 12" THICK	2420	SY	3.50	8,470

TOTAL THIS PAGE $93,048

DATE:03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION SS-2 SOIL COVER
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

JOB # 6853-09

ESTIMATOR: P. R. MARTIN

OPTION SS-2 SOIL COVER SITE PREPARATION AND MOB/DEMOB DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
TOTAL PAGE 2				$93,048
LABORER (2 MEN*10 DAY/MAN*8 HR/DAY)	160	MNHR	30.50	4,880
CARPENTER (2 MEN*10 DAY/MAN*8 HR/DAY)	160	MNHR	39.00	6,240
ELECTRICIAN (2 MEN*10 DAY/MAN*8 HR/DAY	160	MNHR	42.50	6,800
SITE SUPERINTENDANT (3 MON*210 HR/MON)	630	MNHR	62.25	39,218
FOREMAN (3 MON * 210 HR/MON)	630	MNHR	51.75	32,603
CLERK/TYPIST (3 MON * 168 HR/MON)	504	MNHR	26.00	13,104
UNDEVELOPED DESIGN DETAILS ~20%				39,109
TOTAL SITE PREPARATION AND MOB/DEMOB				$235,000

DATE:03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SS-2 SOIL COVER
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SS-2 SOIL COVER

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
CONTAMINATED SOIL DELINEATION				
SAMPLE COLLECTION, 2 MEN, 1 WK	100	HR	56.00	$5,600
ON-SITE ANALYSIS, 2 MEN & EQUIPMEN	7	DAY	4575.00	32,025
OFF-SITE ANALYSIS	100	SMPL	850.00	85,000
UNDEVELOPED DESIGN DETAILS ~20%				24,375
TOTAL CONTAMINATED SOIL DELINEATION				$147,000
INSTITUTIONAL CONTROLS	1	LS	10000.00	$10,000

DATE: 03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SS-2 SOIL COVER
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SS-2 SOIL COVER SOIL COVER DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
SOIL COVER				
PURCHASE COVER MATERIAL	55000	CY	4.00	$220,000
SPREAD & COMPACT	55000	CY	2.00	110,000
TOP SOIL	16000	CY	10.00	160,000
SPREAD & COMPACT	16000	CY	2.00	32,000
SEED, FERTILIZE, MULCH	17	AC	2000.00	34,000
UNDEVELOPED DESIGN DETAILS ~20%				111,000
TOTAL SOIL COVER				$667,000

DATE: 03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SS-2 SOIL COVER
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SS-2 SOIL COVER SURFACE WTER MANAGEMENT DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
SURFACE WATER MANAGEMENT				
DITCH EXCAVATION	1070	CY	2.00	$2,140
BACKFILL DITCH & COMPACT	1070	CY	3.00	3,210
UNDEVELOPED DESIGN DETAILS ~20%				650
TOTAL SURFACE WATER MANAGEMENT				$6,000

DATE:03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SS-2 SOIL COVER
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SS-2 SOIL COVER POST CLOSURE MAINTENANCE DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
ANNUAL COSTS				
ANNUAL INSPECTION & REPORT	8	HR	75.00	$600
ANNUAL MOWING, 5 TIMES/YR	40	HR	50.00	2,000
REPAIRS TO SOIL COVER	5.00%	LS	556000.00	27,800
MAINTENANCE ITEMS OCCURING EVERY 5 YEARS				
SITE REVIEW	1	LS	10000.00	$10,000
		SUBTOTAL		$10,000
ANNUALIZED COST OF MAINTENANCE ITEMS OCCURING EVERY 5 YEARS				1,810
SUBTOTAL ANNUAL COSTS				$32,210
UNDEVELOPED DESIGN DETAILS ~20%				6,790
TOTAL ANNUAL POST CLOSURE MAINTENANCE COSTS				$39,000

DATE: 03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SS-6 IN-SITU SOLIDIFICATION AND SOIL COVER
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SS-6 IN-SITU SOLIDIFICATION AND SOIL COVER
COST SUMMARY TABLE

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
DIRECT COST OF OPTION SS-6 IN-SITU SOLIDIFICATION AND SOIL COVER				
BENCH & PILOT SCALE TESTING				$78,000
SITE PREPARATION AND MOB/DEMOB				540,000
CONTAMINATED SOIL DELINEATION				294,000
IN-SITU STABILIZATION/SOLIDIFICATION INSIDE RACETRACK AND AT CONTAMINATED WASTE AREA				2,137,000
EXCAVATION & PLACEMENT OF SOIL FROM OUTSIDE RACETRACK				120,000
STABILIZATION/SOLIDIFICATION OF SOIL FROM OUTSIDE RACETRACK WITH IN-SITU EQUIPMENT				1,505,000
CONFIRMATORY ANALYSIS				80,000
SOIL COVER				516,000
SURFACE WATER MANAGEMENT				6,000
TOTAL DIRECT COST OF OPTION SS-6 IN-SITU SOLIDIFICATION AND SOIL COVER				$5,276,000
INDIRECT COST OF OPTION SS-6 IN-SITU SOLIDIFICATION AND SOIL COVER				
HEALTH AND SAFETY			5.00%	$264,000
LEGAL, ADMIN, PERMITTING			5.00%	264,000
ENGINEERING			10.00%	528,000
SERVICES DURING CONSTRUCTION			10.00%	528,000
TOTAL INDIRECT COST OF OPTION SS-6 IN-SITU SOLIDIFICATION AND SOIL COVER				$1,584,000
TOTAL CAPITAL (DIRECT + INDIRECT) COST				$6,860,000
OPERATING AND MAINTENANCE COSTS				
TOTAL ANNUAL POST CLOSURE MAINTENANCE COSTS				$31,000
TOTAL PRESENT WORTH OF O&M COSTS (5% FOR THIRTY YEARS)				$477,000
TOTAL COST OF OPTION SS-6 IN-SITU SOLIDIFICATION AND SOIL COVER				$7,337,000

DATE:03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SS-6 IN-SITU SOLIDIFICATION AND SOIL COVER
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SS-6 IN-SITU SOLIDIFICATION AND SOIL COVER
SITE PREPARATION AND MOB/DEMOB

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
EQUIPMENT (IN OR OUT)				
FRONT END LOADER	2	EA	520.00	$1,040
DUMP TRUCKS	4	EA	260.00	1,040
BACKHOE	2	EA	520.00	1,040
DOZER	2	EA	1000.00	2,000
OFFICE TRAILER	7	MON	155.00	1,085
STORAGE TRAILER (2 EA)	14	MON	155.00	2,170
TRAILER SET-UP & DELIVERY, REMOVAL	3	EA	310.00	930
TOILET (2 EA*7 MON/EA*4.2 WK/MON)	60	WK	25.00	1,500
WATER CLR (2EA*7MON/EA*4.2WK/MON)	60	WK	25.00	1,500
WATER (60 WK * 5 DAY/WK)	300	DAY	15.00	4,500
TELEPHONE SERVICE	7	MON	520.00	3,640
ELECTRICAL HOOK-UP	1	LS	2500.00	2,500
ELECTRICAL POWER	7	MON	300.00	2,100
PICK-UP (2 EA * 7 MON/EA)	14	MON	1035.00	14,490
OFFICE EQUIPMENT	7	MON	1035.00	7,245
PUMPS, TOOLS MINOR EQUIPMENT	1	LS	5000.00	5,000
STOCKPILE AREA				
CLEAR & GRUB LIGHT VEGETATION	2	AC	3825.00	7,650
GRADE	3300	CY	2.00	6,600
GRAVEL - 12" THICK	9680	SY	3.50	33,880
PARKING AREA				
CLEAR & GRUB LIGHT VEGETATION	0.5	AC	3825.00	1,913
GRADE	825	CY	2.00	1,650
GRAVEL - 12" THICK	2420	SY	3.50	8,470

TOTAL THIS PAGE $111,943

DATE: 03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SS-6 IN-SITU SOLIDIFICATION AND SOIL COVER
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SS-6 IN-SITU SOLIDIFICATION AND SOIL COVER
SITE PREPARATION AND MOB/DEMOB

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
TOTAL PAGE 2				$111,943
COVERED STORAGE AREA	3200	LF	35.00	112,000
DECON PAD	1	LS	10000.00	10,000
LABORER (2 MEN*10 DAY/MAN*8 HR/DAY)	160	MNHR	30.50	4,880
CARPENTER (2 MEN*10 DAY/MAN*8 HR/DAY)	160	MNHR	39.00	6,240
ELECTRICIAN (2 MEN*10 DAY/MAN*8 HR/DAY	160	MNHR	42.50	6,800
SITE SUPERINTENDANT (7 MON*210 HR/MON)	1470	MNHR	62.25	91,508
FOREMAN (7 MON * 210 HR/MON)	1470	MNHR	51.75	76,073
CLERK/TYPIST (7 MON * 168 HR/MON)	1176	MNHR	26.00	30,576
UNDEVELOPED DESIGN DETAILS ~20%				89,982
TOTAL SITE PREPARATION AND MOB/DEMOB				$540,000

DATE:03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SS-6 IN-SITU SOLIDIFICATION AND SOIL COVER
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SS-6 IN-SITU SOLIDIFICATION AND SOIL COVER TESTING & CONTAMINATED SOIL DELINEATION DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
TESTING				
BENCH SCALE TESTING	1	LS	15000.00	15,000
PILOT SCALE TESTING	1	LS	50000.00	50,000
UNDEVELOPED DESIGN DETAILS ~20%				13,000
TOTAL TESTING				$78,000
CONTAMINATED SOIL DELINEATION				
SAMPLE COLLECTION, 2 MEN, 2 WK	200	HR	56.00	$11,200
ON-SITE ANALYSIS, 2 MEN & EQUIPMEN	14	DAY	4575.00	64,050
OFF-SITE ANALYSIS	200	SMPL	850.00	170,000
UNDEVELOPED DESIGN DETAILS ~20%				48,750
TOTAL CONTAMINATED SOIL DELINEATION				$294,000
IN-SITU STABILIZATION/SOLIDIFICATION INSIDE RACETRACK AND AT CONTAMINATED WASTE AREA				
SOLIDIFICATION	27400	CY	65.00	$1,781,000
UNDEVELOPED DESIGN DETAILS ~20%				356,000
TOTAL IN-SITU STABILIZATION/SOLIDIFICATION INSIDE RACETRAC AND AT CONTAMINATED WASTE AREA				$2,137,000

DATE: 03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SS-6 IN-SITU SOLIDIFICATION AND SOIL COVER
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SS-6 IN-SITU SOLIDIFICATION AND SOIL COVER

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
EXCAVATION AND PLACEMENT OF SOIL FROM OUTSIDE RACETRACK				
300 HP DOZER & OPERATOR - 2 EA	10	DAY	1500.00	$15,000
LABORER - 4 EA	160	HR	30.00	4,800
UNDEVELOPED DESIGN DETAILS ~20%				4,200
TOTAL PER LIFT				$24,000 x5
TOTAL EXCAVATION AND PLACEMENT OF SOIL FROM OUTSIDE RACETRACK				$120,000
IN-SITU STABILIZATION/SOLIDIFICATION OF SOIL FROM OUTSIDE RACETRACK				
SOLIDIFICATION	19300	CY	65.00	$1,254,500
UNDEVELOPED DESIGN DETAILS ~20%				250,500
TOTAL IN-SITU STABILIZATION/SOLIDIFICATION OF SOIL FROM OUTSIDE RACETRACK				$1,505,000
CONFIRMATORY ANALYSIS				
INSIDE RACETRACK	54	TEST	700.00	$37,800
OUTSIDE RACETRACK	41	TEST	700.00	28,700
UNDEVELOPED DESIGN DETAILS ~20%				13,500
TOTAL CONFIRMATORY ANALYSIS				$80,000

DATE: 03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SS-6 IN-SITU SOLIDIFICATION AND SOIL COVER
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SS-6 IN-SITU SOLIDIFICATION AND SOIL COVER
IN-SITU S/S & SURFACE WATER MGMT

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
SOIL COVER				
PURCHASE COVER MATERIAL	47700	CY	4.00	$190,800
SPREAD & COMPACT	47700	CY	2.00	95,400
TOP SOIL	10300	CY	10.00	103,000
SPREAD & COMPACT	10300	CY	2.00	20,600
SEED, FERTILIZE, MULCH	10	AC	2000.00	20,000
UNDEVELOPED DESIGN DETAILS ~20%				86,200
TOTAL SOIL COVER				$516,000
SURFACE WATER MANAGEMENT				
DITCH EXCAVATION	1070	CY	2.00	$2,140
BACKFILL DITCH & COMPACT	1070	CY	3.00	3,210
UNDEVELOPED DESIGN DETAILS ~20%				650
TOTAL SURFACE WATER MANAGEMENT				$6,000

DATE: 03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SS-6 IN-SITU SOLIDIFICATION AND SOIL COVER
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SS-6 IN-SITU SOLIDIFICATION AND SOIL COVER

POST CLOSURE MAINTENANCE DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
ANNUAL COSTS				
ANNUAL INSPECTION & REPORT	8	HR	75.00	$600
ANNUAL MOWING, 5 TIMES/YR	40	HR	50.00	2,000
REPAIRS TO SOIL COVER	5.00%	LS	429800.00	21,490
MAINTENANCE ITEMS OCCURING EVERY 5 YEARS				
SITE REVIEW	1	LS	10000.00	$10,000
SUBTOTAL				$10,000
ANNUALIZED COST OF MAINTENANCE ITEMS OCCURING EVERY 5 YEARS				1,810
SUBTOTAL ANNUAL COSTS				$25,900
UNDEVELOPED DESIGN DETAILS ~20%				5,100
TOTAL ANNUAL POST CLOSURE MAINTENANCE COSTS				$31,000

DATE:03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SB-1 MINIMAL ACTION
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SB-1 MINIMAL ACTION COST SUMMARY TABLE DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
DIRECT COST OF OPTION SB-1 MINIMAL ACTION				
INSTITUTIONAL CONTROLS				$10,000
TOTAL DIRECT COST OF OPTION SB-1 MINIMAL ACTION				$10,000
INDIRECT COST OF OPTION SB-1 MINIMAL ACTION				
HEALTH AND SAFETY			0.00%	$0
LEGAL, ADMIN, PERMITTING			0.00%	0
ENGINEERING			0.00%	0
SERVICES DURING CONSTRUCTION			0.00%	0
TOTAL INDIRECT COST OF OPTION SB-1 MINIMAL ACTION				$0
TOTAL CAPITAL (DIRECT + INDIRECT) COST				$10,000
OPERATING AND MAINTENANCE COSTS				
TOTAL ANNUAL OPERATING AND MAINTENANCE COSTS				$7,000
TOTAL PRESENT WORTH OF ANNUAL O&M COSTS (5% FOR THIRTY YEARS)				$108,000
TOTAL PRESENT WORTH OF OPERATING AND MAINTENANCE COSTS				$108,000
TOTAL COST OF OPTION SB-1 MINIMAL ACTION				$118,000

DATE: 03-Aug-94

UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION SB-1 MINIMAL ACTION

JOB # 6853-09

LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT

ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SB-1 MINIMAL ACTION

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
INSTITUTIONAL CONTROLS	1	LS	10000.00	$10,000
ANNUAL OPERATING & MAINTENANCE COSTS				
EDUCATIONAL PROGRAMS	1	LS	5000.00	$5,000
FIVE YEAR SITE REVIEW @ $10,000 EVERY FIVE YEARS	1	LS	1809.75	1,810
CONTINGENCY ~10%				190
TOTAL ANNUAL OPERATING & MAINTENANCE COSTS				$7,000

DATE: 03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION SB-2 CAPPING JOB # 6853-09
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SB-2 CAPPING COST SUMMARY TABLE DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
DIRECT COST OF OPTION SB-2 CAPPING				
SITE PREPARATION AND MOB/DEMOB				$198,000
ROADWAY IMPROVEMENT				22,000
CONTAMINATED SOIL DELINEATION				80,000
CAP CONSTRUCTION				654,000
INSTITUTIONAL CONTROLS				10,000
TOTAL DIRECT COST OF OPTION SB-2 CAPPING				$964,000
INDIRECT COST OF OPTION SB-2 CAPPING				
HEALTH AND SAFETY			5.00%	$48,000
LEGAL, ADMIN, PERMITTING			5.00%	48,000
ENGINEERING			10.00%	96,000
SERVICES DURING CONSTRUCTION			10.00%	96,000
TOTAL INDIRECT COST OF OPTION SB-2 CAPPING				$288,000
TOTAL CAPITAL (DIRECT + INDIRECT) COST				$1,252,000
OPERATING AND MAINTENANCE COSTS				
TOTAL ANNUAL OPERATING AND MAINTENANCE COSTS				$7,000
TOTAL PRESENT WORTH OF O&M COSTS (5% FOR THIRTY YEARS)				$108,000
TOTAL COST OF OPTION SB-2 CAPPING				$1,360,000

DATE:03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION SB-2 CAPPING
JOB # 6853-09

LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT

ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SB-2 CAPPING SITE PREPARATION AND MOB/DEMOB DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
EQUIPMENT (IN OR OUT)				
FRONT END LOADER	2	EA	520.00	$1,040
DUMP TRUCKS	2	EA	260.00	520
DOZER	2	EA	520.00	1,040
OFFICE TRAILER	3	MON	155.00	465
STORAGE TRAILER (2 EA)	6	MON	155.00	930
TRAILER SET-UP & DELIVERY, REMOVAL	3	EA	310.00	930
TOILET (2 EA*3 MON/EA*4.2 WK/MON)	26	WK	25.00	650
WATER CLR (2EA*3MON/EA*4.2WK/MON)	26	WK	25.00	650
WATER (26 WK * 5 DAY/WK)	130	DAY	15.00	1,950
TELEPHONE SERVICE	3	MON	520.00	1,560
ELECTRICAL HOOK-UP	1	LS	2500.00	2,500
ELECTRICAL POWER	3	MON	300.00	900
PICK-UP (2 EA * 3 MON/EA)	6	MON	1035.00	6,210
OFFICE EQUIPMENT	3	MON	1035.00	3,105
PUMPS, TOOLS MINOR EQUIPMENT	1	LS	5000.00	5,000
CLEAR AND GRUB STUMPS - LIGHT TREES	1	AC	3825.00	3,825
STAGING & PARKING - 2 AREAS OF 1/4 AC PER EACH				
12" GRAVEL	2420	SY	6.50	15,730
SOIL STOCKPILE AREAS, 2 AREAS OF 1 AC PER EACH				
CLEAR AND GRUB STUMPS - LIGHT TREE	2	AC	3825.00	7,650
GRADE	3220	CY	2.00	6,440
EARTH BERM - FROM ON-SITE SOIL	480	CY	2.00	960

TOTAL THIS PAGE $62,055

DATE: 03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SB-2 CAPPING
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SB-2 CAPPING SITE PREPARATION AND MOB/DEMOB DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
TOTAL PAGE 2				$62,055
LABORER (2 MEN*10 DAY/MAN*8 HR/DAY)	160	MNHR	30.50	4,880
CARPENTER (2 MEN*10 DAY/MAN*8 HR/DAY)	160	MNHR	39.00	6,240
ELECTRICIAN (2 MEN*10 DAY/MAN*8 HR/DAY	160	MNHR	42.50	6,800
SITE SUPERINTENDANT (3 MON*210 HR/MON)	630	MNHR	62.25	39,218
FOREMAN (3 MON * 210 HR/MON)	630	MNHR	51.75	32,603
CLERK/TYPIST (3 MON * 168 HR/MON)	504	MNHR	26.00	13,104
UNDEVELOPED DESIGN DETAILS ~20%				33,101
TOTAL SITE PREPARATION AND MOB/DEMOB				$198,000

DATE:03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SB-2 CAPPING
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SB-2 CAPPING

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
ROADWAY IMPROVEMENT				
COMPACT EXISTING ROADWAY	800	SY	1.00	$800
16" GRAVEL BASE	800	SY	6.00	4,800
4" BINDER LAYER	800	SY	10.00	8,000
2" WEARING LAYER	800	SY	5.50	4,400
UNDEVELOPED DESIGN DETAILS ~20%				4,000
TOTAL ROADWAY IMPROVEMENT				$22,000
CONTAMINATED SOIL DELINEATION				
DRILLING COSTS	12	BRG	770.00	$9,240
SAMPLE COLLECTION	80	HR	56.00	4,480
ON-SITE ANALYSIS, 2 MEN & EQUIPMEN	5	DAY	4575.00	22,875
OFF-SITE ANALYSIS	50	SMPL	600.00	30,000
UNDEVELOPED DESIGN DETAILS ~20%				13,405
TOTAL CONTAMINATED SOIL DELINEATION				$80,000
INSTITUTIONAL CONTROLS	1	LS	10000.00	$10,000

DATE: 03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION SB-2 CAPPING
JOB # 6853-09
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SB-2 CAPPING CAP CONSTRUCTION DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
CAP CONSTRUCTION (1 PIT @ 3 AC & 1 PIT @ 1 AC)				
CLAY - DELIVERED	12900	CY	8.00	$103,200
SPREAD & COMPACT CLAY	12900	CY	4.00	51,600
60 MIL VLDPE	19400	SY	8.00	155,200
DRAINAGE SAND	6450	CY	8.00	51,600
FILTER FABRIC	1940	SY	4.00	7,760
COMMON BORROW	12900	CY	4.00	51,600
TOP SOIL	6450	CY	10.00	64,500
SPREAD & COMPACT SAND, COMMON BORROW, TOP SOIL	25800	CY	2.00	51,600
SEED, FERTILIZE, MULCH	4	AC	2000.00	8,000
UNDEVELOPED DESIGN DETAILS ~20%				108,940
TOTAL CAP CONSTRUCTION				$654,000

DATE:03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SB-2 CAPPING
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SB-2 CAPPING ANNUAL O&M COSTS DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
ANNUAL COSTS				
ANNUAL INSPECTION & REPORT	20	HR	75.00	$1,500
ANNUAL MOWING	8	HR	50.00	400
MAINTENANCE ITEMS OCCURING EVERY 5 YEARS				
SITE REVIEW	1	LS	10000.00	$10,000
SAMPLING COLLECTION AND ANALYSIS	2	EA	5000.00	10,000
		SUBTOTAL		$20,000
ANNUALIZED COST OF MAINTENANCE ITEMS OCCURING EVERY 5 YEARS				$3,619
SUBTOTAL ANNUAL COSTS				$5,519
UNDEVELOPED DESIGN DETAILS ~20%				1,481
TOTAL ANNUAL POST CLOSURE MAINTENANCE COSTS				$7,000

DATE:03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SB-3 EXCAVATION AND OFF-SITE LANDFILL
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SB-3 EXCAVATION AND OFF-SITE LANDFILL COST SUMMARY TABLE DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
DIRECT COST OF OPTION SB-3 EXCAVATION AND OFF-SITE LANDFILL				
SITE PREPARATION AND MOB/DEMOB				$208,000
ROADWAY IMPROVEMENT				22,000
DELINEATION OF SOIL CONTAMINATION				116,000
EXCAVATION, TRANSPORTATION, DISPOSAL, AND BACKFILL				1,841,000
TOTAL DIRECT COST OF OPTION SB-3 EXCAVATION AND OFF-SITE LANDFILL				$2,187,000
INDIRECT COST OF OPTION SB-3 EXCAVATION AND OFF-SITE LANDFILL				
HEALTH AND SAFETY			5.00%	$48,000
LEGAL, ADMIN, PERMITTING			5.00%	48,000
ENGINEERING			10.00%	96,000
SERVICES DURING CONSTRUCTION			10.00%	96,000
TOTAL INDIRECT COST OF OPTION SB-3 EXCAVATION AND OFF-SITE LANDFILL				$288,000
TOTAL CAPITAL (DIRECT + INDIRECT) COST				$2,475,000
OPERATING AND MAINTENANCE COSTS				
TOTAL ANNUAL OPERATING AND MAINTENANCE COSTS				$0
TOTAL PRESENT WORTH OF O&M COSTS (5% FOR THIRTY YEARS)				$0
TOTAL COST OF OPTION SB-3 EXCAVATION AND OFF-SITE LANDFILL				$2,475,000

DATE:03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SB-3 EXCAVATION AND OFF-SITE LANDFILL
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SB-3 EXCAVATION AND OFF-SITE LANDFILL
SITE PREPARATION AND MOB/DEMOB

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
EQUIPMENT (IN OR OUT)				
FRONT END LOADER	2	EA	520.00	$1,040
DUMP TRUCKS	2	EA	260.00	520
DOZER	2	EA	520.00	1,040
OFFICE TRAILER	2	MON	155.00	310
STORAGE TRAILER (2 EA)	4	MON	155.00	620
TRAILER SET-UP & DELIVERY, REMOVAL	3	EA	310.00	930
TOILET (2 EA*2 MON/EA*4.2 WK/MON)	17	WK	25.00	425
WATER CLR (2EA*2MON/EA*4.2WK/MON)	17	WK	25.00	425
WATER (17 WK * 5 DAY/WK)	85	DAY	15.00	1,275
TELEPHONE SERVICE	2	MON	520.00	1,040
ELECTRICAL HOOK-UP	1	LS	2500.00	2,500
ELECTRICAL POWER	2	MON	300.00	600
PICK-UP (2 EA * 2 MON/EA)	4	MON	1035.00	4,140
OFFICE EQUIPMENT	2	MON	1035.00	2,070
PUMPS, TOOLS MINOR EQUIPMENT	1	LS	5000.00	5,000
CLEAR AND GRUB STUMPS - LIGHT TREES	1	AC	3825.00	3,825
STAGING & PARKING - 2 AREAS OF 1/4 AC PER EACH				
12" GRAVEL	2420	SY	6.50	15,730
DECON PAD	1	EA	10000.00	10,000
DECON MATERIALS & EQUIPMENT	1	LS	2500.00	2,500
SOIL STOCKPILE AREAS, UNCONTAMINATED SOIL - 1 ACRE & UNTREATED SOIL - 1/2 ACRE				
CLEAR AND GRUB STUMPS - LIGHT TREE	1.5	AC	3825.00	5,738
GRADE	2420	CY	2.00	4,840
EARTH BERM - FROM ON-SITE SOIL	360	CY	2.00	720
FOR UNTRETED SOIL STOCKPILE AREA ADD -				
	2415	SY	6.00	14,490
6" SAND LAYER	1200	CY	12.50	15,000
DRAIN SUMP	1	LS	2500.00	2,500
DRAIN PIPE	300	LF	5.00	1,500
TOTAL THIS PAGE				$98,778

DATE:03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SB-3 EXCAVATION AND OFF-SITE LANDFILL
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SB-3 EXCAVATION AND OFF-SITE LANDFILL
SITE PREPARATION AND MOB/DEMOB

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
TOTAL PAGE 2				$98,778
LABORER (2 MEN*10 DAY/MAN*8 HR/DAY)	160	MNHR	30.50	4,880
CARPENTER (2 MEN*10 DAY/MAN*8 HR/DAY)	160	MNHR	39.00	6,240
ELECTRICIAN (2 MEN*10 DAY/MAN*8 HR/DAY	160	MNHR	42.50	6,800
SITE SUPERINTENDANT (2 MON*210 HR/MON)	420	MNHR	62.25	26,145
FOREMAN (2 MON * 210 HR/MON)	420	MNHR	51.75	21,735
CLERK/TYPIST (2 MON * 168 HR/MON)	336	MNHR	26.00	8,736
UNDEVELOPED DESIGN DETAILS ~20%				34,687
TOTAL SITE PREPARATION AND MOB/DEMOB				$208,000

DATE: 03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SB-3 EXCAVATION AND OFF-SITE LANDFILL
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SB-3 EXCAVATION AND OFF-SITE LANDFILL
ROADWAY IMPROVEMENT AND DELINEATION OF SOIL CO

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
ROADWAY IMPROVEMENT				
COMPACT EXISTING ROADWAY	800	SY	1.00	$800
16" GRAVEL BASE	800	SY	6.00	4,800
4" BINDER LAYER	800	SY	10.00	8,000
2" WEARING LAYER	800	SY	5.50	4,400
UNDEVELOPED DESIGN DETAILS ~20%				4,000
TOTAL ROADWAY IMPROVEMENT				$22,000
DELINEATION OF SOIL CONTAMINATION				
DRILLING COSTS	18	BRG	770.00	$13,860
SAMPLE COLLECTION	100	HR	56.00	5,600
ON-SITE ANALYSIS, 2 MEN & EQUIPMEN	7	DAY	4575.00	32,025
OFF-SITE ANALYSIS	75	SMPL	600.00	45,000
UNDEVELOPED DESIGN DETAILS ~20%				19,515
TOTAL DELINEATION OF SOIL CONTAMINATION				$116,000

DATE: 03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SB-3 EXCAVATION AND OFF-SITE LANDFILL
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SB-3 EXCAVATION AND OFF-SITE LANDFILL
EXCAVATION, TRANSPORTATION, DISPOSAL, AND BACK

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
UNCONTAMINATED EXCAVATION (12350 CY)				
BACKHOE & OPERATOR	15	DAY	1350.00	$20,250
DUMP TRUCK & DRIVER - 3 EA	45	DAY	650.00	29,250
LABORER - 2 EA	240	MNHR	30.00	7,200
CONTAMINATED EXCAVATION (6100 CY/(16 LOAD/DAY * 20 CY/LOAD)) ~ 20 DAYS				
BACKHOE & OPERATOR	20	DAY	1350.00	27,000
DUMP TRUCK & DRIVER	20	DAY	650.00	13,000
LABORER - 2 EA	320	MNHR	30.00	9,600
LEVEL D PROTECTION	60	MNDAY	30.00	1,800
SEGREGATION				
PORTABLE SCREEN	20	DAY	175.00	3,500
LABORER	160	MNHR	30.00	4,800
FRONT END LOADER & OPERATOR	20	DAY	800.00	16,000
LEVEL D PROTECTION	40	MNDAY	30.00	1,200
TRANSPORTATION				
MENOMONEE FALLS	275	LOAD	563.00	154,825
FT. WAYNE	30	LOAD	1831.25	54,938
DISPOSAL				
WASTE APPROVAL FEE	2	LS	500.00	1,000
MENOMONEE FALLS	5904	TON	142.50	841,320
FT. WAYNE	700	TON	280.00	196,000
BACKFILL				
BORROW MATERIAL	4050	CY	12.50	50,625
BACKHOE & OPERATOR	20	DAY	1350.00	$27,000
DUMP TRUCK & DRIVER - 3 EA	20	DAY	650.00	13,000
LABORER - 2 EA	320	MNHR	30.00	9,600
COMPACTION	20	DAY	1450.00	29,000
TOPSOIL, FURNISH & SPREAD	1050	CY	20.00	21,000
SEED, FERTILIZE, MULCH	1.25	AC	2000.00	2,500
UNDEVELOPED DESIGN DETAILS ~20%				306,593
TOTAL EXCAVATION, TRANSPORTATION, DISPOSAL, AND BACKFILL				$1,841,000

DATE: 03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SB-3 EXCAVATION AND OFF-SITE LANDFILL
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTIOOPTION SB-2 EXCAVATION AND OFF-SITE LANDFILL
ANNUAL O&M COSTS

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
NOTHING REQUIRED				

DATE: 03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION WP-1 MINIMAL ACTION
JOB # 6853-09
LOCATION: PROPELLANT BURNING GROUND WASTE PITS
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION WP-1 MINIMAL ACTION COST SUMMARY TABLE DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
DIRECT COST OF OPTION WP-1 MINIMAL ACTION				
INSTITUTIONAL CONTROLS				$10,000
TOTAL DIRECT COST OF OPTION WP-1 MINIMAL ACTION				$10,000
INDIRECT COST OF OPTION WP-1 MINIMAL ACTION				
HEALTH AND SAFETY			0.00%	$0
LEGAL, ADMIN, PERMITTING			0.00%	0
ENGINEERING			0.00%	0
SERVICES DURING CONSTRUCTION			0.00%	0
TOTAL INDIRECT COST OF OPTION GW-1 MINIMAL ACTION				$0
TOTAL CAPITAL (DIRECT + INDIRECT) COST				$10,000
OPERATING AND MAINTENANCE COSTS				
TOTAL ANNUAL OPERATING AND MAINTENANCE COSTS				$6,000
TOTAL PRESENT WORTH OF ANNUAL O&M COSTS (5% FOR THIRTY YEARS)				$92,000
TOTAL PRESENT WORTH OF OPERATING AND MAINTENANCE COSTS				$92,000
TOTAL COST OF OPTION WP-1 MINIMAL ACTION				$102,000

DATE: 03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION WP-1 MINIMAL ACTION
LOCATION: PROPELLANT BURNING GROUND WASTE PITS
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION WP-1 MINIMAL ACTION

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
INSTITUTIONAL CONTROLS	1	LS	10000.00	$10,000
ANNUAL OPERATING & MAINTENANCE COSTS				
EDUCATIONAL PROGRAMS	1	LS	5000.00	$5,000
FIVE YEAR SITE REVIEW @ $10,000 EVERY FIVE YEARS	1	LS		
CONTINGENCY ~10%				1,000
TOTAL ANNUAL OPERATING & MAINTENANCE COSTS				$6,000

DATE:03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION WP-4 ON-SITE INCINERATION AND CAPPING
LOCATION: PROPELLANT BURNING GROUND WASTE PITS
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION WP-4 ON-SITE INCINERATION AND CAPPING
COST SUMMARY TABLE

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
DIRECT COST OF OPTION WP-4 ON-SITE INCINERATION AND CAPPING				
SITE PREPARATION AND MOB/DEMOB				$2,415,000
CONTAMINATED SOIL DELINEATION				138,000
EXCAVATE, BLEND, AND SCREEN CONTAMINATED SOIL				401,000
BACKFILL SOIL				209,000
INCINERATION				1,832,000
CAP CONSTRUCTION				138,000
INSTITUTIONAL CONTROLS				10,000
TOTAL DIRECT COST OF OPTION WP-4 ON-SITE INCINERATION AND CAPPING				$5,143,000
INDIRECT COST OF OPTION WP-4 ON-SITE INCINERATION AND CAPPING				
HEALTH AND SAFETY			5.00%	$257,000
LEGAL, ADMIN, PERMITTING			5.00%	257,000
ENGINEERING			10.00%	514,000
SERVICES DURING CONSTRUCTION			10.00%	514,000
TOTAL INDIRECT COST OF OPTION WP-4 ON-SITE INCINERATION AND CAPPING				$1,542,000
TOTAL CAPITAL (DIRECT + INDIRECT) COST				$6,685,000
OPERATING AND MAINTENANCE COSTS				
TOTAL ANNUAL POST CLOSURE MAINTENANCE COSTS				$7,000
TOTAL PRESENT WORTH OF O&M COSTS (5% FOR THIRTY YEARS)				$108,000
TOTAL COST OF OPTION WP-4 ON-SITE INCINERATION AND CAPPING				$6,793,000

DATE: 03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION WP-4 ON-SITE INCINERATION AND CAPPING
LOCATION: PROPELLANT BURNING GROUND WASTE PITS
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION WP-4 ON-SITE INCINERATION AND CAPPING
SITE PREPARATION AND MOB/DEMOB

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
EQUIPMENT (IN OR OUT)				
FRONT END LOADER	8	EA	520.00	$4,160
DUMP TRUCKS	44	EA	260.00	11,440
BACKHOE	6	EA	520.00	3,120
DOZER	4	EA	1000.00	4,000
INCINERATOR	1	LS	1700000.00	1,700,000
OFFICE TRAILER	3	MON	155.00	465
STORAGE TRAILER (2 EA)	6	MON	155.00	930
TRAILER SET-UP & DELIVERY, REMOVAL	3	EA	310.00	930
TOILET (2 EA*3 MON/EA*4.2 WK/MON)	25	WK	25.00	625
WATER CLR (2EA*3MON/EA*4.2WK/MON)	25	WK	25.00	625
WATER (25 WK * 5 DAY/WK)	125	DAY	15.00	1,875
TELEPHONE SERVICE	3	MON	520.00	1,560
ELECTRICAL HOOK-UP	1	LS	2500.00	2,500
ELECTRICAL POWER	3	MON	300.00	900
PICK-UP (2 EA * 3 MON/EA)	6	MON	1035.00	6,210
OFFICE EQUIPMENT	3	MON	1035.00	3,105
PUMPS, TOOLS MINOR EQUIPMENT	1	LS	5000.00	5,000
CLEAN SOIL STOCKPILE AREA				
CLEAR & GRUB LIGHT VEGETATION	2	AC	3825.00	7,650
GRADE	3300	CY	2.00	6,600
GRAVEL - 12" THICK	9680	SY	3.50	33,880
PARKING AREA				
CLEAR & GRUB LIGHT VEGETATION	0.5	AC	3825.00	1,913
GRADE	825	CY	2.00	1,650
GRAVEL - 12" THICK	2420	SY	3.50	8,470
UNTREATED SOIL STOCKPILE AREA				
CLEAR & GRUB LIGHT VEGETATION	0.25	AC	3825.00	956
GRADE	400	CY	2.00	800
EARTH BERM FROM GRADED SOIL	400	CY	2.00	800
GRAVEL - 12" THICK	1210	SY	3.50	4,235
40 MIL LINER	1210	SY	6.00	7,260
6" SAND	200	CY	10.00	2,000
SUMP	1	LS	2500.00	2,500
DRAIN PIPE	200	LF	5.00	1,000
TOTAL THIS PAGE				$1,827,159

DATE:03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION WP-4 ON-SITE INCINERATION AND CAPPING
LOCATION: PROPELLANT BURNING GROUND WASTE PITS
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION WP-4 ON-SITE INCINERATION AND CAPPING SITE PREPARATION AND MOB/DEMOB DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
TOTAL PAGE 2				$1,827,159
TREATED SOIL STOCKPILE AREA				
CLEAR & GRUB LIGHT VEGETATION	0.75	AC	3825.00	2,869
GRADE	1225	CY	2.00	2,450
GRAVEL - 12" THICK	3630	SY	3.50	12,705
6" SAND	600	CY	10.00	6,000
INCINERATOR SITE				
CLEAR & GRUB LIGHT VEGETATION	2	AC	3825.00	7,650
GRADE	3300	CY	2.00	6,600
GRAVEL - 12" THICK	9680	SY	3.50	33,880
DECON PAD	1	LS	10000.00	10,000
LABORER (2 MEN*10 DAY/MAN*8 HR/DAY)	160	MNHR	30.50	4,880
CARPENTER (2 MEN*10 DAY/MAN*8 HR/DAY)	160	MNHR	39.00	6,240
ELECTRICIAN (2 MEN*10 DAY/MAN*8 HR/DAY	160	MNHR	42.50	6,800
SITE SUPERINTENDANT (3 MON*210 HR/MON)	630	MNHR	62.25	39,218
FOREMAN (3 MON * 210 HR/MON)	630	MNHR	51.75	32,603
CLERK/TYPIST (3 MON * 168 HR/MON)	504	MNHR	26.00	13,104
UNDEVELOPED DESIGN DETAILS ~20%				402,844
TOTAL SITE PREPARATION AND MOB/DEMOB				$2,415,000

DATE: 03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION WP-4 ON-SITE INCINERATION AND CAPPING
LOCATION: PROPELLANT BURNING GROUND WASTE PITS
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION WP-4 ON-SITE INCINERATION AND CAPPING CONTAMINATED SOIL DELINEATION DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
CONTAMINATED SOIL DELINEATION				
DRILLING	63	BRG	875.00	$55,125
ON-SITE ANALYSIS	25	DAY	960.00	24,000
OFF-SITE ANALYSIS	40	SMPL	900.00	36,000
UNDEVELOPED DESIGN DETAILS ~20%				22,875
TOTAL CONTAMINATED SOIL DELINEATION				$138,000
INSTITUTIONAL CONTROLS	1	LS	10000.00	$10,000

DATE: 03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION WP-4 ON-SITE INCINERATION AND CAPPING
LOCATION: PROPELLANT BURNING GROUND WASTE PITS
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION WP-4 ON-SITE INCINERATION AND CAPPING
EXCAVATE CONTAMINATED SOIL & BACKFILL

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
EXCAVATE CLEAN SOIL, 16000 CY/PIT, 3 PITS, 5 DAY/PIT				
BACKHOE & OPERATOR (2 EA)	10	DAY	3000.00	$30,000
DUMP TRUCK & DRIVER (10 EA)	50	DAY	650.00	32,500
LABORER (2 EA)	80	HR	30.00	2,400
DOZER & OPERATOR	5	DAY	1450.00	7,250
EXCAVATE CONTAMINATED SOIL, 1240 CY/PIT, 5 DAY/PIT				
BACKHOE & OPERATOR	5	DAY	3000.00	15,000
DUMP TRUCK & DRIVER (2 EA)	10	DAY	650.00	6,500
LABORER (2 EA)	80	HR	30.00	2,400
SCREEN	5	DAY	175.00	875
BACKHOE & OPERATOR, 1 SHIFT/DAY	5	SHIFT	800.00	4,000
BACKHOE & OPERATOR, 3 SHIFT/DAY	15	SHIFT	700.00	10,500
SUBTOTAL PER PIT				$111,425
FOR 3 PITS				X3
TOTAL FOR 3 PITS				$334,275
UNDEVELOPED DESIGN DETAILS ~20%				66,725
TOTAL EXCAVATE, BLEND, AND SCREEN CONTAMINATED SOIL				$401,000
BACKFILL SOIL, 18000 CY/PIT, 5 DAY/PIT				
FRONT END LOADER & OPERATOR (2 EA)	10	DAY	1600.00	$16,000
DUMP TRUCK & DRIVER (10 EA)	50	DAY	650.00	32,500
DOZER & OPERATOR	5	DAY	1450.00	7,250
LABORER (2 EA)	80	HR	30.00	2,400
SUBTOTAL PER PIT				$58,150
FOR 3 PITS				X3
TOTAL FOR 3 PITS				$174,450
UNDEVELOPED DESIGN DETAILS ~20%				34,550
TOTAL BACKFILL SOIL				$209,000

DATE: 03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION WP-4 ON-SITE INCINERATION AND CAPPING
LOCATION: PROPELLANT BURNING GROUND WASTE PITS
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION WP-4 ON-SITE INCINERATION AND CAPPING
INCINERATION & CAP CONSTRUCTION

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
INCINERATION				
PERMITTING	1	LS	200000.00	$200,000
INCINERATION FEE	6000	TON	200.00	1,200,000
ANALYTICAL	40	SMPL	900.00	36,000
SECONDARY WASTE STREAM DISPOSAL				
TRANSPORTATION	19	LOAD	513.00	9,747
LINER FEE	19	LOAD	50.00	950
DISPOSAL	563	TON	142.50	80,228
UNDEVELOPED DESIGN DETAILS ~20%				305,076
TOTAL INCINERATION				$1,832,000
CAP CONSTRUCTION (3 PIT @ 0.25 AC/PIT)				
CLAY - DELIVERED	2420	CY	8.00	$19,360
SPREAD & COMPACT CLAY	2420	CY	4.00	9,680
60 MIL VLDPE	3630	SY	8.00	29,040
DRAINAGE SAND	1210	CY	8.00	9,680
FILTER FABRIC	3630	SY	4.00	14,520
COMMON BORROW	2420	CY	4.00	9,680
TOP SOIL	1210	CY	10.00	12,100
SPREAD & COMPACT SAND, COMMON BORROW, TOP SOIL	4840	CY	2.00	9,680
SEED, FERTILIZE, MULCH	0.75	AC	2000.00	1,500
UNDEVELOPED DESIGN DETAILS ~20%				22,760
TOTAL CAP CONSTRUCTION				$138,000

DATE:03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION WP-4 ON-SITE INCINERATION AND CAPPING
LOCATION: PROPELLANT BURNING GROUND WASTE PITS
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION WP-4 ON-SITE INCINERATION AND CAPPING POST CLOSURE MAINTENANCE DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
ANNUAL COSTS				
ANNUAL INSPECTION & REPORT	20	HR	75.00	$1,500
ANNUAL MOWING	8	HR	50.00	400
MAINTENANCE ITEMS OCCURING EVERY 5 YEARS				
SITE REVIEW	1	LS	10000.00	$10,000
SAMPLING COLLECTION AND ANALYSIS	2	EA	5000.00	10,000
		SUBTOTAL		$20,000
ANNUALIZED COST OF MAINTENANCE ITEMS OCCURING EVERY 5 YEARS				$3,619
SUBTOTAL ANNUAL COSTS				$5,519
UNDEVELOPED DESIGN DETAILS ~20%				1,481
TOTAL ANNUAL POST CLOSURE MAINTENANCE COSTS				$7,000

DATE: 03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION WP-5 ON-SITE COMPOSTING AND CAPPING
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION WP-5 ON-SITE COMPOSTING AND CAPPING
COST SUMMARY TABLE

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
DIRECT COST OF OPTION WP-5 ON-SITE COMPOSTING AND CAPPING				
TREATABILITY TESTING				$30,000
SITE PREPARATION AND MOB/DEMOB				719,000
CONTAMINATED SOIL DELINEATION				138,000
EXCAVATE, BLEND, AND SCREEN CONTAMINATED SOIL				401,000
BACKFILL SOIL				209,000
COMPOSTING				1,600,000
CAP CONSTRUCTION				138,000
INSTITUTIONAL CONTROLS				10,000
TOTAL DIRECT COST OF OPTION WP-5 ON-SITE COMPOSTING AND CAPPING				$3,245,000
INDIRECT COST OF OPTION WP-5 ON-SITE COMPOSTING AND CAPPING				
HEALTH AND SAFETY			5.00%	$162,000
LEGAL, ADMIN, PERMITTING			5.00%	162,000
ENGINEERING			10.00%	325,000
SERVICES DURING CONSTRUCTION			10.00%	325,000
TOTAL INDIRECT COST OF OPTION WP-5 ON-SITE COMPOSTING AND CAPPING				$974,000
TOTAL CAPITAL (DIRECT + INDIRECT) COST				$4,219,000
OPERATING AND MAINTENANCE COSTS				
O&M OF COMPOSTING SYSTEM FOR 1 YEAR				$1,085,000
TOTAL PRESENT WORTH OF O&M COSTS (5% FOR ONE YEAR)				$1,033,000
TOTAL ANNUAL POST CLOSURE MAINTENANCE COSTS				$7,000
TOTAL PRESENT WORTH OF POST CLOSURE O&M COSTS (5% FOR THIRTY YEARS)				$108,000
TOTAL PRESENT WORTH OF O&M COSTS				$1,141,000
TOTAL COST OF OPTION WP-5 ON-SITE COMPOSTING AND CAPPING				$5,360,000

DATE:03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION WP-5 ON-SITE COMPOSTING AND CAPPING
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION WP-5 ON-SITE COMPOSTING AND CAPPING
SITE PREPARATION AND MOB/DEMOB

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
EQUIPMENT (IN OR OUT)				
FRONT END LOADER	8	EA	520.00	$4,160
DUMP TRUCKS	44	EA	260.00	11,440
BACKHOE	6	EA	520.00	3,120
DOZER	4	EA	1000.00	4,000
OFFICE TRAILER	3	MON	155.00	465
STORAGE TRAILER (2 EA)	6	MON	155.00	930
TRAILER SET-UP & DELIVERY, REMOVAL	3	EA	310.00	930
TOILET (2 EA*3 MON/EA*4.2 WK/MON)	25	WK	25.00	625
WATER CLR (2EA*3MON/EA*4.2WK/MON)	25	WK	25.00	625
WATER (25 WK * 5 DAY/WK)	125	DAY	15.00	1,875
TELEPHONE SERVICE	3	MON	520.00	1,560
ELECTRICAL HOOK-UP	1	LS	2500.00	2,500
ELECTRICAL POWER	3	MON	300.00	900
PICK-UP (2 EA * 3 MON/EA)	6	MON	1035.00	6,210
OFFICE EQUIPMENT	3	MON	1035.00	3,105
PUMPS, TOOLS MINOR EQUIPMENT	1	LS	5000.00	5,000
CLEAN SOIL STOCKPILE AREA				
CLEAR & GRUB LIGHT VEGETATION	2	AC	3825.00	7,650
GRADE	3300	CY	2.00	6,600
GRAVEL - 12" THICK	9680	SY	3.50	33,880
PARKING AREA				
CLEAR & GRUB LIGHT VEGETATION	0.5	AC	3825.00	1,913
GRADE	825	CY	2.00	1,650
GRAVEL - 12" THICK	2420	SY	3.50	8,470
TOTAL THIS PAGE				$107,608

DATE:03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION WP-5 ON-SITE COMPOSTING AND CAPPING
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION WP-5 ON-SITE COMPOSTING AND CAPPING
SITE PREPARATION AND MOB/DEMOB

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
TOTAL PAGE 2				$107,608
UNTREATED SOIL STOCKPILE AREA				
CLEAR & GRUB LIGHT VEGETATION	0.25	AC	3825.00	956
GRADE	400	CY	2.00	800
EARTH BERM FROM GRADED SOIL	400	CY	2.00	800
GRAVEL - 12" THICK	1210	SY	3.50	4,235
40 MIL LINER	1210	SY	6.00	7,260
6" SAND	200	CY	10.00	2,000
SUMP	1	LS	2500.00	2,500
DRAIN PIPE	200	LF	5.00	1,000
TEMPORARY STRUCTURE	11000	SF	20.00	220,000
TREATED SOIL STOCKPILE AREA				
CLEAR & GRUB LIGHT VEGETATION	0.75	AC	3825.00	2,869
GRADE	1225	CY	2.00	2,450
GRAVEL - 12" THICK	3630	SY	3.50	12,705
6" SAND	600	CY	10.00	6,000
COMPOSTING AREA				
CLEAR & GRUB LIGHT VEGETATION	3	AC	3825.00	11,475
GRADE	4950	CY	2.00	9,900
GRAVEL - 6" THICK	14520	SY	1.75	25,410
ASPHALT PAD	85000	SF	0.80	68,000
DECON PAD	1	LS	10000.00	10,000
LABORER (2 MEN*10 DAY/MAN*8 HR/DAY)	160	MNHR	30.50	4,880
CARPENTER (2 MEN*10 DAY/MAN*8 HR/DAY)	160	MNHR	39.00	6,240
ELECTRICIAN (2 MEN*10 DAY/MAN*8 HR/DAY	160	MNHR	42.50	6,800
SITE SUPERINTENDANT (3 MON*210 HR/MON)	630	MNHR	62.25	39,218
FOREMAN (3 MON * 210 HR/MON)	630	MNHR	51.75	32,603
CLERK/TYPIST (3 MON * 168 HR/MON)	504	MNHR	26.00	13,104
UNDEVELOPED DESIGN DETAILS ~20%				120,189
TOTAL SITE PREPARATION AND MOB/DEMOB				$719,000

DATE:03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION WP-5 ON-SITE COMPOSTING AND CAPPING
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION WP-5 ON-SITE COMPOSTING AND CAPPING

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
CONTAMINATED SOIL DELINEATION				
DRILLING	63	BRG	875.00	$55,12
ON-SITE ANALYSIS	25	DAY	960.00	24,00
OFF-SITE ANALYSIS	40	SMPL	900.00	36,00
UNDEVELOPED DESIGN DETAILS ~20%				22,87
TOTAL CONTAMINATED SOIL DELINEATION				$138,00
INSTITUTIONAL CONTROLS	1	LS	10000.00	$10,00
TREATABILITY TESTING	1	LS	30000.00	$30,00

DATE:03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION WP-5 ON-SITE COMPOSTING AND CAPPING
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION WP-5 ON-SITE COMPOSTING AND CAPPING
EXCAVATE CONTAMINATED SOIL & BACKFILL

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
EXCAVATE CLEAN SOIL, 16000 CY/PIT, 3 PITS, 5 DAY/PIT				
BACKHOE & OPERATOR (2 EA)	10	DAY	3000.00	$30,000
DUMP TRUCK & DRIVER (10 EA)	50	DAY	650.00	32,500
LABORER (2 EA)	80	HR	30.00	2,400
DOZER & OPERATOR	5	DAY	1450.00	7,250
EXCAVATE CONTAMINATED SOIL, 1240 CY/PIT, 5 DAY/PIT				
BACKHOE & OPERATOR	5	DAY	3000.00	15,000
DUMP TRUCK & DRIVER (2 EA)	10	DAY	650.00	6,500
LABORER (2 EA)	80	HR	30.00	2,400
SCREEN	5	DAY	175.00	875
FRONT END LOADER & OPER, 1 SHIFT/D	5	SHIFT	800.00	4,000
FRONT END LOADER & OPER, 3 SHIFT/D	15	SHIFT	700.00	10,500
SUBTOTAL PER PIT				$111,425
FOR 3 PITS				X3
TOTAL FOR 3 PITS				$334,275
UNDEVELOPED DESIGN DETAILS ~20%				66,725
TOTAL EXCAVATE, BLEND, AND SCREEN CONTAMINATED SOIL				$401,000
BACKFILL SOIL, 18000 CY/PIT, 5 DAY/PIT				
FRONT END LOADER & OPERATOR (2 EA)	10	DAY	1600.00	$16,000
DUMP TRUCK & DRIVER (10 EA)	50	DAY	650.00	32,500
DOZER & OPERATOR	5	DAY	1450.00	7,250
LABORER (2 EA)	80	HR	30.00	2,400
SUBTOTAL PER PIT				$58,150
FOR 3 PITS				X3
TOTAL FOR 3 PITS				$174,450
UNDEVELOPED DESIGN DETAILS ~20%				34,550
TOTAL BACKFILL SOIL				$209,000

DATE: 03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION WP-5 ON-SITE COMPOSTING AND CAPPING
JOB # 6853-09
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION WP-5 ON-SITE COMPOSTING AND CAPPING COMPOSTING & CAP CONSTRUCTION DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
COMPOSTING				
WINDROW STRUCTURES				
12 MONTH RENTAL	12	MON	92532.00	$1,110,384
EQUIPMENT STORAGE BLDG	1	EA	20000.00	20,000
DELIVERY	1	LS	12000.00	12,000
SOIL TURNING EQUIPMENT RENTAL	12	MON	10500.00	126,000
FRONT END LOADER RENTAL	12	MON	3000.00	36,000
HAUL TRUCK RENTAL	12	MON	2400.00	28,800
UNDEVELOPED DESIGN DETAILS ~20%				266,816
TOTAL COMPOSTING				$1,600,000
CAP CONSTRUCTION (3 PIT @ 0.25 AC/PIT)				
CLAY - DELIVERED	2420	CY	8.00	$19,360
SPREAD & COMPACT CLAY	2420	CY	4.00	9,680
60 MIL VLDPE	3630	SY	8.00	29,040
DRAINAGE SAND	1210	CY	8.00	9,680
FILTER FABRIC	3630	SY	4.00	14,520
COMMON BORROW	2420	CY	4.00	9,680
TOP SOIL	1210	CY	10.00	12,100
SPREAD & COMPACT SAND, COMMON BORROW, TOP SOIL	4840	CY	2.00	9,680
SEED, FERTILIZE, MULCH	0.75	AC	2000.00	1,500
UNDEVELOPED DESIGN DETAILS ~20%				22,760
TOTAL CAP CONSTRUCTION				$138,000

DATE: 03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION WP-5 ON-SITE COMPOSTING AND CAPPING
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION WP-5 ON-SITE COMPOSTING AND CAPPING
POST CLOSURE MAINTENANCE

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
ANNUAL COSTS				
ANNUAL INSPECTION & REPORT	20	HR	75.00	$1,500
ANNUAL MOWING	8	HR	50.00	400
MAINTENANCE ITEMS OCCURING EVERY 5 YEARS				
SITE REVIEW	1	LS	10000.00	$10,000
SAMPLING COLLECTION AND ANALYSIS	2	EA	5000.00	10,000
		SUBTOTAL		$20,000
ANNUALIZED COST OF MAINTENANCE ITEMS OCCURING EVERY 5 YEARS				$3,619
SUBTOTAL ANNUAL COSTS				$5,519
UNDEVELOPED DESIGN DETAILS ~20%				1,481
TOTAL ANNUAL POST CLOSURE MAINTENANCE COSTS				$7,000
COMPOSTING O&M COSTS - FOR 1 YEAR				
EQUIPMENT - FUEL, ELECTRICITY, MAINTENANCE	40	WK	4000.00	$160,000
LABOR - 6 EA	40	WK	5500.00	220,000
AMENDMENT	7600	TON	50.00	380,000
ANALYTICAL	160	SMPL	900.00	144,000
UNDEVELOPED DESIGN DETAILS ~20%				181,000
TOTAL COMPOSTING O&M COSTS - FOR 1 YEAR				$1,085,000

DATE: 03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION WP-7 IN-SITU VACUUM EXTRACTION, COMPOSTING, AND CAPPING
JOB # 6853-09

LOCATION: PROPELLANT BURNING GROUND WASTE PITS
BADGER ARMY AMMUNITION PLANT

ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION WP-7 IN-SITU VACUUM EXTRACTION, COMPOSTING, AND CAPPING
COST SUMMARY TABLE

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
DIRECT COST OPTION WP-7 IN-SITU VACUUM EXTRACTION, COMPOSTING, AND CAPPING				
TREATABILITY TESTING				$90,000
CONTAMINATED SOIL DELINEATION				138,000
SITE PREPARATION AND MOB/DEMOB				719,000
IN-SITU VACUUM EXTRACTION SYSTEM CONSTRUCTION				103,000
IN-SITU VACUUM EXTRACTION SYSTEM OPERATION				20,000
EXCAVATE, BLEND, AND SCREEN CONTAMINATED SOIL				401,000
BACKFILL				209,000
COMPOSTING				1,600,000
CAP CONSTRUCTION				138,000
TOTAL DIRECT COST OPTION WP-7 IN-SITU VACUUM EXTRACTION, COMPOSTING, AND CAPPING				$3,418,000
INDIRECT COST OPTION WP-7 IN-SITU VACUUM EXTRACTION, COMPOSTING, AND CAPPING				
HEALTH AND SAFETY			5.00%	$171,000
LEGAL, ADMIN, PERMITTING			5.00%	171,000
ENGINEERING			10.00%	342,000
SERVICES DURING CONSTRUCTION			10.00%	342,000
TOTAL INDIRECT COST OPTION WP-7 IN-SITU VACUUM EXTRACTION, COMPOSTING, AND CAPPING				$1,026,000
TOTAL CAPITAL (DIRECT + INDIRECT) COST				$4,444,000
OPERATING AND MAINTENANCE COSTS				
O&M OF COMPOSTING SYSTEM FOR 1 YEAR				$1,085,000
TOTAL PRESENT WORTH OF COMPOSTING O&M COSTS (5% FOR ONE YEAR)				$1,033,000
TOTAL ANNUAL POST CLOSURE OPERATING AND MAINTENANCE COSTS				$7,000
TOTAL PRESENT WORTH OF POST CLOSURE O&M COSTS (5% FOR THIRTY YEARS)				$108,000
TOTAL PRESENT WORTH OF O&M COSTS				$1,141,000
TOTAL COST OPTION WP-7 IN-SITU VACUUM EXTRACTION, COMPOSTING, AND CAPPING				$5,585,000

DATE:03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION WP-7 IN-SITU VACUUM EXTRACTION, COMPOSTING, AND CAPPING
JOB # 6853-09

LOCATION: PROPELLANT BURNING GROUND WASTE PITS
BADGER ARMY AMMUNITION PLANT

ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION WP-7 IN-SITU VACUUM EXTRACTION, COMPOSTING, AND CAPPING
SITE PREPARATION AND MOB/DEMOB

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
EQUIPMENT (IN OR OUT)				
FRONT END LOADER	8	EA	520.00	$4,160
DUMP TRUCKS	44	EA	260.00	11,440
BACKHOE	6	EA	520.00	3,120
DOZER	4	EA	1000.00	4,000
OFFICE TRAILER	3	MON	155.00	465
STORAGE TRAILER (2 EA)	6	MON	155.00	930
TRAILER SET-UP & DELIVERY, REMOVAL	3	EA	310.00	930
TOILET (2 EA*3 MON/EA*4.2 WK/MON)	25	WK	25.00	625
WATER CLR (2EA*3MON/EA*4.2WK/MON)	25	WK	25.00	625
WATER (25 WK * 5 DAY/WK)	125	DAY	15.00	1,875
TELEPHONE SERVICE	3	MON	520.00	1,560
ELECTRICAL HOOK-UP	1	LS	2500.00	2,500
ELECTRICAL POWER	3	MON	300.00	900
PICK-UP (2 EA * 3 MON/EA)	6	MON	1035.00	6,210
OFFICE EQUIPMENT	3	MON	1035.00	3,105
PUMPS, TOOLS MINOR EQUIPMENT	1	LS	5000.00	5,000
CLEAN SOIL STOCKPILE AREA				
CLEAR & GRUB LIGHT VEGETATION	2	AC	3825.00	7,650
GRADE	3300	CY	2.00	6,600
GRAVEL - 12" THICK	9680	SY	3.50	33,880
PARKING AREA				
CLEAR & GRUB LIGHT VEGETATION	0.5	AC	3825.00	1,913
GRADE	825	CY	2.00	1,650
GRAVEL - 12" THICK	2420	SY	3.50	8,470

TOTAL THIS PAGE $107,608

DATE: 03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION WP-7 IN-SITU VACUUM EXTRACTION, COMPOSTING, AND CAPPING JOB # 6853-09
LOCATION: PROPELLANT BURNING GROUND WASTE PITS
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION WP-7 IN-SITU VACUUM EXTRACTION, COMPOSTING, AND CAPPING
SITE PREPARATION AND MOB/DEMOB

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
TOTAL PAGE 2				$107,608
UNTREATED SOIL STOCKPILE AREA				
CLEAR & GRUB LIGHT VEGETATION	0.25	AC	3825.00	956
GRADE	400	CY	2.00	800
EARTH BERM FROM GRADED SOIL	400	CY	2.00	800
GRAVEL - 12" THICK	1210	SY	3.50	4,235
40 MIL LINER	1210	SY	6.00	7,260
6" SAND	200	CY	10.00	2,000
SUMP	1	LS	2500.00	2,500
DRAIN PIPE	200	LF	5.00	1,000
TEMPORARY STRUCTURE	11000	SF	20.00	220,000
TREATED SOIL STOCKPILE AREA				
CLEAR & GRUB LIGHT VEGETATION	0.75	AC	3825.00	2,869
GRADE	1225	CY	2.00	2,450
GRAVEL - 12" THICK	3630	SY	3.50	12,705
6" SAND	600	CY	10.00	6,000
COMPOSTING AREA				
CLEAR & GRUB LIGHT VEGETATION	3	AC	3825.00	11,475
GRADE	4950	CY	2.00	9,900
GRAVEL - 6" THICK	14520	SY	1.75	25,410
ASPHALT PAD	85000	SF	0.80	68,000
DECON PAD	1	LS	10000.00	10,000
LABORER (2 MEN*10 DAY/MAN*8 HR/DAY)	160	MNHR	30.50	4,880
CARPENTER (2 MEN*10 DAY/MAN*8 HR/DAY)	160	MNHR	39.00	6,240
ELECTRICIAN (2 MEN*10 DAY/MAN*8 HR/DAY	160	MNHR	42.50	6,800
SITE SUPERINTENDANT (3 MON*210 HR/MON)	630	MNHR	62.25	39,218
FOREMAN (3 MON * 210 HR/MON)	630	MNHR	51.75	32,603
CLERK/TYPIST (3 MON * 168 HR/MON)	504	MNHR	26.00	13,104
UNDEVELOPED DESIGN DETAILS ~20%				120,189
TOTAL SITE PREPARATION AND MOB/DEMOB				$719,000

DATE: 03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION WP-7 IN-SITU VACUUM EXTRACTION, COMPOSTING, AND CAPPING
LOCATION: PROPELLANT BURNING GROUND WASTE PITS
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION WP-7 IN-SITU VACUUM EXTRACTION, COMPOSTING, AND CAPPING

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
TREATABILITY TESTING				
COMPOSTING	1	LS	30000.00	$30,000
SVE PILOT TEST	1	LS	45000.00	45,000
UNDEVELOPED DESIGN DETAILS ~20%				15,000
TOTAL TREATABILITY TESTING				$90,000
CONTAMINATED SOIL DELINEATION				
DRILLING	63	BRG	875.00	$55,125
ON-SITE ANALYSIS	25	DAY	960.00	24,000
OFF-SITE CONFIRMATORY ANALYSIS	40	SMPL	900.00	36,000
UNDEVELOPED DESIGN DETAILS ~20%				22,875
TOTAL CONTAMINATED SOIL DELINEATION				$138,000

DATE: 03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION WP-7 IN-SITU VACUUM EXTRACTION, COMPOSTING, AND CAPPING
LOCATION: PROPELLANT BURNING GROUND WASTE PITS
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION WP-7 IN-SITU VACUUM EXTRACTION, COMPOSTING, AND CAPPING

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
IN-SITU VACUUM EXTRACTION SYSTEM CONSTRUCTION				
EXTRACTION WELL	2	EA	8500.00	$17,000
VADOSE MONITORING WELLS	6	EA	8000.00	48,000
PIPE & FITTINGS	1	LS	1000.00	1,000
BLOWER RENTAL	1	LS	1634.00	1,634
TEMPORARY BUILDING	1	LS	10000.00	10,000
CARBON ADSORBER RENTAL				
FIRST MONTH	2	EA	1995.00	3,990
ADDITIONAL MONTHS FOR 2 EA	5	MON	590.00	2,950
CARBON REACTIVATION	1	LS	200.00	200
ANALYTICAL	1	LS	1425.00	1,425
UNDEVELOPED DESIGN DETAILS ~20%				16,801
TOTAL IN-SITU VACUUM EXTRACTION SYSTEM CONSTRUCTION				$103,000
IN-SITU VACUUM EXTRACTION SYSTEM OPERATION				
DAILY MONITORING	180	HR	30.00	$5,400
WEEKLY MONITORING	48	HR	75.00	3,600
ANALYTICAL	144	SMPL	50.00	7,200
POWER - 5 HP	16300	KWHR	0.04	652
UNDEVELOPED DESIGN DETAILS ~20%				3,148
TOTAL IN-SITU VACUUM EXTRACTION SYSTEM OPERATION				$20,000

DATE: 03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION WP-7 IN-SITU VACUUM EXTRACTION,
COMPOSTING, AND CAPPING
LOCATION: PROPELLANT BURNING GROUND WASTE PITS
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION WP-7 IN-SITU VACUUM EXTRACTION, COMPOSTING, AND CAPPING
EXCAVATE CONTAMINATED SOIL & BACKFILL

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
EXCAVATE CLEAN SOIL, 16000 CY/PIT, 3 PITS, 5 DAY/PIT				
BACKHOE & OPERATOR (2 EA)	10	DAY	3000.00	$30,000
DUMP TRUCK & DRIVER (10 EA)	50	DAY	650.00	32,500
LABORER (2 EA)	80	HR	30.00	2,400
DOZER & OPERATOR	5	DAY	1450.00	7,250
EXCAVATE CONTAMINATED SOIL, 1240 CY/PIT, 5 DAY/PIT				
BACKHOE & OPERATOR	5	DAY	3000.00	15,000
DUMP TRUCK & DRIVER (2 EA)	10	DAY	650.00	6,500
LABORER (2 EA)	80	HR	30.00	2,400
SCREEN	5	DAY	175.00	875
FRONT END LOADER & OPER, 1 SHIFT/D	5	SHIFT	800.00	4,000
FRONT END LOADER & OPER, 3 SHIFT/D	15	SHIFT	700.00	10,500
SUBTOTAL PER PIT				$111,425
FOR 3 PITS				X3
TOTAL FOR 3 PITS				$334,275
UNDEVELOPED DESIGN DETAILS ~20%				66,725
TOTAL EXCAVATE, BLEND, AND SCREEN CONTAMINATED SOIL				$401,000
BACKFILL SOIL, 18000 CY/PIT, 5 DAY/PIT				
FRONT END LOADER & OPERATOR (2 EA)	10	DAY	1600.00	$16,000
DUMP TRUCK & DRIVER (10 EA)	50	DAY	650.00	32,500
DOZER & OPERATOR	5	DAY	1450.00	7,250
LABORER (2 EA)	80	HR	30.00	2,400
SUBTOTAL PER PIT				$58,150
FOR 3 PITS				X3
TOTAL FOR 3 PITS				$174,450
UNDEVELOPED DESIGN DETAILS ~20%				34,550
TOTAL BACKFILL SOIL				$209,000

DATE: 03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION WP-7 IN-SITU VACUUM EXTRACTION, COMPOSTING, AND CAPPING
JOB # 6853-09

LOCATION: PROPELLANT BURNING GROUND WASTE PITS
BADGER ARMY AMMUNITION PLANT

ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION WP-7 IN-SITU VACUUM EXTRACTION, COMPOSTING, AND CAPPING

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
COMPOSTING				
WINDROW STRUCTURES				
12 MONTH RENTAL	12	MON	92532.00	$1,110,384
EQUIPMENT STORAGE BLDG	1	EA	20000.00	20,000
DELIVERY	1	LS	12000.00	12,000
SOIL TURNING EQUIPMENT RENTAL	12	MON	10500.00	126,000
FRONT END LOADER RENTAL	12	MON	3000.00	36,000
HAUL TRUCK RENTAL	12	MON	2400.00	28,800
UNDEVELOPED DESIGN DETAILS ~20%				266,816
TOTAL COMPOSTING				$1,600,000
CAP CONSTRUCTION (3 PIT @ 0.25 AC/PIT)				
CLAY - DELIVERED	2420	CY	8.00	$19,360
SPREAD & COMPACT CLAY	2420	CY	4.00	9,680
60 MIL VLDPE	3630	SY	8.00	29,040
DRAINAGE SAND	1210	CY	8.00	9,680
FILTER FABRIC	3630	SY	4.00	14,520
COMMON BORROW	2420	CY	4.00	9,680
TOP SOIL	1210	CY	10.00	12,100
SPREAD & COMPACT SAND, COMMON BORROW, TOP SOIL	4840	CY	2.00	9,680
SEED, FERTILIZE, MULCH	0.75	AC	2000.00	1,500
UNDEVELOPED DESIGN DETAILS ~20%				22,760
TOTAL CAP CONSTRUCTION				$138,000

DATE: 03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION WP-7 IN-SITU VACUUM EXTRACTION, COMPOSTING, AND CAPPING

JOB # 6853-09

LOCATION: PROPELLANT BURNING GROUND WASTE PITS
BADGER ARMY AMMUNITION PLANT

ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION WP-7 IN-SITU VACUUM EXTRACTION, COMPOSTING, AND CAPPING
POST CLOSURE MAINTENANCE

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
ANNUAL COSTS				
ANNUAL INSPECTION & REPORT	20	HR	75.00	$1,500
ANNUAL MOWING	8	HR	50.00	400
MAINTENANCE ITEMS OCCURING EVERY 5 YEARS				
SITE REVIEW	1	LS	10000.00	$10,000
SAMPLING COLLECTION AND ANALYSIS	2	EA	5000.00	10,000
		SUBTOTAL		$20,000
ANNUALIZED COST OF MAINTENANCE ITEMS OCCURING EVERY 5 YEARS				$3,619
SUBTOTAL ANNUAL COSTS				$5,519
UNDEVELOPED DESIGN DETAILS ~20%				1,481
TOTAL ANNUAL POST CLOSURE MAINTENANCE COSTS				$7,000
COMPOSTING O&M COSTS				
EQUIPMENT - FUEL, ELECTRICITY, MAINTENANCE	40	WK	4000.00	$160,000
LABOR - 6 EA	40	WK	5500.00	220,000
AMENDMENT	7600	TON	50.00	380,000
ANALYTICAL	160	SMPL	900.00	144,000
UNDEVELOPED DESIGN DETAILS ~20%				181,000
TOTAL COMPOSTING O&M COSTS				$1,085,000

DATE: 03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION WP-8 IN-SITU TREATMENT
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION WP-8 IN-SITU TREATMENT COST SUMMARY TABLE DESCRIPTION		TOTAL COST SOIL FLUSHING	CHEMICAL/ BIOLOGICAL
DIRECT COST OF OPTION WP-8 IN-SITU TREATMENT			
TREATABILITY TESTING		$528,000	$528,000
SITE PREPARATION AND MOB/DEMOB		347,000	347,000
CONTAMINATED SOIL DELINEATION		365,000	365,000
BARRIER SYSTEM CONSTRUCTION		7,928,000	7,928,000
INFILTRATION BASIN CONSTRUCTION		295,000	--
WATER TABLE EXTRACTION WELL INSTALLATION		247,000	--
CONFIRMATORY SAMPLING		53,000	53,000
ADDITION OF IRON SULFATE AND HYDROGEN PEROXIDE, pH ADJUSTMENT, AND ADDITION OF NUTRIENTS		--	(O&M)
TOTAL DIRECT COST OF OPTION WP-8 IN-SITU TREATMENT		$9,763,000	$9,221,000
INDIRECT COST OF OPTION WP-8 IN-SITU TREATMENT			
HEALTH AND SAFETY	5.00%	$488,000	$461,000
LEGAL, ADMIN, PERMITTING	5.00%	488,000	461,000
ENGINEERING	10.00%	976,000	922,000
SERVICES DURING CONSTRUCTION	10.00%	976,000	922,000
TOTAL INDIRECT COST OF OPTION WP-8 IN-SITU TREATMENT		$2,928,000	$2,766,000
TOTAL CAPITAL (DIRECT + INDIRECT) COST		$12,691,000	$11,987,000
OPERATING AND MAINTENANCE COSTS			
TOTAL ANNUAL OPERATING AND MAINTENANCE COSTS		$349,000	$10,754,000
TOTAL PRESENT WORTH OF O&M COSTS (STARTING 2 YEARS AFTER BEGINNING PROJECT)			
(5% FOR 11 YEARS)		$2,629,000	
(5% FOR 16 MONTHS)			$12,287,000
TOTAL COST OF OPTION WP-8 IN-SITU TREATMENT		$15,320,000	$24,274,000

DATE:03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION WP-8 IN-SITU TREATMENT
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION WP-8 IN-SITU TREATMENT SITE PREPARATION AND MOB/DEMOB DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
EQUIPMENT (IN OR OUT)				
FRONT END LOADER	2	EA	520.00	$1,040
DUMP TRUCKS	4	EA	260.00	1,040
BACKHOE	2	EA	520.00	1,040
OFFICE TRAILER	3	MON	155.00	465
STORAGE TRAILER (2 EA)	6	MON	155.00	930
TRAILER SET-UP & DELIVERY, REMOVAL	3	EA	310.00	930
TOILET (2 EA*3 MON/EA*4.2 WK/MON)	25	WK	25.00	625
WATER CLR (2EA*3MON/EA*4.2WK/MON)	25	WK	25.00	625
WATER (25 WK * 5 DAY/WK)	125	DAY	15.00	1,875
TELEPHONE SERVICE	3	MON	520.00	1,560
ELECTRICAL HOOK-UP	1	LS	2500.00	2,500
ELECTRICAL POWER	3	MON	300.00	900
PICK-UP (2 EA * 3 MON/EA)	6	MON	1035.00	6,210
OFFICE EQUIPMENT	3	MON	1035.00	3,105
PUMPS, TOOLS MINOR EQUIPMENT	1	LS	5000.00	5,000
STAGING AREA				
CLEAR & GRUB LIGHT VEGETATION	1	AC	3825.00	3,825
GRADE	1650	CY	2.00	3,300
GRAVEL - 12" THICK	4840	SY	3.50	16,940
TEMPORARY COVERED AREA	3200	SF	35.00	112,000
PARKING AREA				
CLEAR & GRUB LIGHT VEGETATION	0.5	AC	3825.00	1,913
GRADE	825	CY	2.00	1,650
GRAVEL - 12" THICK	2420	SY	3.50	8,470
DECON PAD	1	LS	10000.00	10,000
TOTAL THIS PAGE				$185,943

DATE: 03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION WP-8 IN-SITU TREATMENT
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION WP-8 IN-SITU TREATMENT SITE PREPARATION AND MOB/DEMOB DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
TOTAL PAGE 2				$185,943
LABORER (2 MEN*10 DAY/MAN*8 HR/DAY)	160	MNHR	30.50	4,880
CARPENTER (2 MEN*10 DAY/MAN*8 HR/DAY)	160	MNHR	39.00	6,240
ELECTRICIAN (2 MEN*10 DAY/MAN*8 HR/DAY	160	MNHR	42.50	6,800
SITE SUPERINTENDANT (3 MON*210 HR/MON)	630	MNHR	62.25	39,218
FOREMAN (3 MON * 210 HR/MON)	630	MNHR	51.75	32,603
CLERK/TYPIST (3 MON * 168 HR/MON)	504	MNHR	26.00	13,104
UNDEVELOPED DESIGN DETAILS ~20%				58,214
TOTAL SITE PREPARATION AND MOB/DEMOB				$347,000

DATE: 03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION WP-8 IN-SITU TREATMENT
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION WP-8 IN-SITU TREATMENT

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
CONTAMINATED SOIL DELINEATION				
DRILLING	63	BRG	2915.00	$183,645
ON-SITE ANALYSIS	55	DAY	935.00	51,425
OFF-SITE ANALYSIS	77	SMPL	900.00	69,300
UNDEVELOPED DESIGN DETAILS ~20%				60,630
TOTAL CONTAMINATED SOIL DELINEATION				$365,000
TREATABILITY TESTING				
BARRIER SYSTEM TESTS	1	LS	235000.00	$235,000
FLUSHING SOLUTION EFFECTIVENESS TE	1	LS	20000.00	20,000
PILOT SCALE SOIL FLUSHING TESTS	1	LS	85000.00	85,000
CHEMICAL/BIOLOGICAL TESTS	1	LS	100000.00	100,000
UNDEVELOPED DESIGN DETAILS ~20%				88,000
TOTAL SOIL FLUSHING TREATABILITY TESTING				$528,000
BARRIER SYSTEM CONSTRUCTION				
VENDOR QUOTE	1	LS	6607000.00	$6,607,000
UNDEVELOPED DESIGN DETAILS ~20%				1,321,000
TOTAL BARRIER SYSTEM CONSTRUCTION				$7,928,000

DATE: 03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION WP-8 IN-SITU TREATMENT
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION WP-8 IN-SITU TREATMENT INFILTRATION BASIN CONSTRUCTION DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
STRIP FINE-GRAINED SOIL FROM WASTE PITS & DISPOSE OF				
BACKHOE & OPERATOR	3	DAY	1350.00	$4,050
LABORER	24	HR	30.00	720
TRANSPORTATION	12	LOAD	513.00	6,156
LINER FEE	12	LOAD	50.00	600
DISPOSAL	327	TON	142.50	46,598
SAND-CEMENT BERM	840	CY	75.00	63,000
PLACE GRAVELLY SAND FILL	2180	CY	10.00	21,800
SOIL FLUSHING PIPE				
4" DIA SOLID PVC	330	LF	21.50	7,095
1" DIA PERFORATED PVC	1800	LF	20.00	36,000
SOIL FLUSHING TRANSPORT PIPE				
4" DIA SOLID PVC	1400	LF	21.50	30,100
CONN TO PRODUCTION WELL NO. 5	1	LS	1000.00	1,000
INFLUENT PIPE				
4" DIA SOLID PVC	1300	LF	21.50	27,950
CONNECT TO EXISTING PIPE	1	LS	500.00	500
UNDEVELOPED DESIGN DETAILS ~20%				49,432
TOTAL INFILTRATION BASIN CONSTRUCTION				$295,000

DATE:03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION WP-8 IN-SITU TREATMENT
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION WP-8 IN-SITU TREATMENT

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
WATER TABLE EXTRACTION WELL				
EXTRACTION WELLS	3	EA	28500.00	$85,500
PUMPS & CONTROLS	3	EA	40000.00	120,000
UNDEVELOPED DESIGN DETAILS ~20%				41,500
TOTAL WATER TABLE EXTRACTION WELL				$247,000
CONFIRMATORY SAMPLING				
DRILLING AND SAMPLING	3	BRG	5700.00	$17,100
ANALYSIS	30	SMPL	900.00	27,000
UNDEVELOPED DESIGN DETAILS ~20%				8,900
TOTAL CONFIRMATORY SAMPLING				$53,000

DATE: 03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION WP-8 IN-SITU TREATMENT
JOB # 6853-09
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION WP-8 IN-SITU TREATMENT

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
CHEMICAL/BIOLOGICAL TREATMENT (IGT CBT PROCESS)				
MOB/DEMOB	1	LS	80000.00	$80,000
LABOR - 7 MAN CREW	852	SHIFT	4500.00	3,834,000
EQUIPMENT - CRANE & AIR HANDLING	852	SHIFT	3500.00	2,982,000
ON-SITE BATCH PLANT	852	SHIFT	1000.00	852,000
MATERIALS (CHEMICALS, NUTRIENTS, FUEL, ETC)	852	SHIFT	4930.00	4,200,360
UNDEVELOPED DESIGN DETAILS ~20%				2,389,640
TOTAL CHEMICAL/BIOLOGICAL TREATMENT				$14,338,000

TREATMENT TIME IS 16 MONTHS. TREATMENT STARTS 2 YEARS AFTER BEGINNING OF PROJECT (1 YEAR FOR TESTING AND 1 YEAR FOR BARRIER CONSTRUCTION).

ANNUAL TREATMENT COST IS 12/16 OF TOTAL ABOVE $10,754,000

DATE: 03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION WP-8 IN-SITU TREATMENT
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

JOB # 6853-09

ESTIMATOR: P. R. MARTIN

OPTION WP-8 IN-SITU TREATMENT ANNUAL O&M COSTS DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
ANNUAL IN-SITU SOIL FLUSHING OPERATION				
IRM FACILITY OPERATION				
PUMPING ELECTRICAL LOAD - 90 KW	788400	KWHR	0.04	$31,536
CARBON REPLACEMENT	9	TIMES	15500.00	139,500
LABOR - 8 HR/WK	416	HR	40.00	16,640
BUILDING LIGHT & POWER	96360	KWHR	0.04	3,854
SAMPLING (4 SAMPLES BIWEEKLY)				
EPA MTD 624 VOAs	104	EA	275.00	28,600
EPA MTD 625 SVOAs	104	EA	518.00	53,872
INORGANICS	104	EA	163.00	16,952
UNDEVELOPED DESIGN DETAILS ~20%				58,046
TOTAL ANNUAL IN-SITU SOIL FLUSHING OPERATION				$349,000

TREATMENT TIME IS 11 YEARS. TREATMENT STARTS 2 YEARS AFTER BEGINNING OF PROJECT (1 YEAR FOR TESTING AND 1 YEAR FOR BAR CONSTRUCTION).

DATE: 03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION WP-10 ON-SITE INCINERATION
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION WP-10 ON-SITE INCINERATION COST SUMMARY TABLE DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
DIRECT COST OF OPTION WP-10 ON-SITE INCINERATION				
SITE PREPARATION AND MOB/DEMOB				$5,244,000
CONTAMINATED SOIL DELINEATION				365,000
DIAPHRAGM WALL CONSTRUCTION				10,500,000
EXCAVATION OF CONTAMINATED SOIL				(O&M)
INCINERATION				(O&M)
BACKFILL				(O&M)
TOTAL DIRECT COST OF OPTION WP-10 ON-SITE INCINERATION				$16,109,000
INDIRECT COST OF OPTION WP-10 ON-SITE INCINERATION				
HEALTH AND SAFETY			5.00%	$805,000
LEGAL, ADMIN, PERMITTING			5.00%	805,000
ENGINEERING			10.00%	1,611,000
SERVICES DURING CONSTRUCTION			10.00%	1,611,000
TOTAL INDIRECT COST OF OPTION WP-10 ON-SITE INCINERATION				$4,832,000
TOTAL CAPITAL (DIRECT + INDIRECT) COST				$20,941,000
OPERATING AND MAINTENANCE COSTS				
TOTAL ANNUAL OPERATING AND MAINTENANCE COSTS				$21,307,000
TOTAL PRESENT WORTH OF O&M COSTS (STARTING 1 YEAR AFTER BEGINNING PROJECT). (5% FOR 1.5 YEARS)				$28,641,000
TOTAL COST OF OPTION WP-10 ON-SITE INCINERATION				$49,582,000

DATE:03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION WP-10 ON-SITE INCINERATION
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

JOB # 6853-09

ESTIMATOR: P. R. MARTIN

OPTION WP-10 ON-SITE INCINERATION SITE PREPARATION AND MOB/DEMOB DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
EQUIPMENT (IN OR OUT)				
FRONT END LOADER	8	EA	520.00	$4,160
DUMP TRUCKS	14	EA	260.00	3,640
BACKHOE	8	EA	520.00	4,160
DOZER	4	EA	1000.00	4,000
INCINERATOR	1	LS	3000000.00	3,000,000
OFFICE TRAILER	30	MON	155.00	4,650
STORAGE TRAILER (2 EA)	60	MON	155.00	9,300
TRAILER SET-UP & DELIVERY, REMOVAL	3	EA	310.00	930
TOILET (2 EA*2.5 YR/EA*52 WK/YR)	260	WK	25.00	6,500
WATER CLR (2 EA*2.5 YR/EA*52 WK/YR)	260	WK	25.00	6,500
WATER (84 WK * 5 DAY/WK)	1300	DAY	15.00	19,500
TELEPHONE SERVICE	30	MON	520.00	15,600
ELECTRICAL HOOK-UP	1	LS	2500.00	2,500
ELECTRICAL POWER	30	MON	300.00	9,000
PICK-UP (2 EA * 30 MON/EA)	60	MON	1035.00	62,100
OFFICE EQUIPMENT	30	MON	1035.00	31,050
PUMPS, TOOLS MINOR EQUIPMENT	1	LS	5000.00	5,000
STAGING AREA				
CLEAR & GRUB LIGHT VEGETATION	1	AC	3825.00	3,825
GRADE	1650	CY	2.00	3,300
GRAVEL - 12" THICK	4840	SY	3.50	16,940
TEMPORARY COVERED AREA	3200	SF	35.00	112,000
PARKING AREA				
CLEAR & GRUB LIGHT VEGETATION	0.5	AC	3825.00	1,913
GRADE	825	CY	2.00	1,650
GRAVEL - 12" THICK	2420	SY	3.50	8,470
UNTREATED SOIL STOCKPILE AREA				
CLEAR & GRUB LIGHT VEGETATION	0.25	AC	3825.00	956
GRADE	400	CY	2.00	800
EARTH BERM FROM GRADED SOIL	400	CY	2.00	800
GRAVEL - 12" THICK	1210	SY	3.50	4,235
40 MIL LINER	1210	SY	6.00	7,260
6" SAND	200	CY	10.00	2,000
SUMP	1	LS	2500.00	2,500
DRAIN PIPE	200	LF	5.00	1,000
TOTAL THIS PAGE				$3,356,239

DATE:03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION WP-10 ON-SITE INCINERATION
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

JOB # 6853-09

ESTIMATOR: P. R. MARTIN

OPTION WP-10 ON-SITE INCINERATION SITE PREPARATION AND MOB/DEMOB DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
TOTAL PAGE 2				$3,356,239
TREATED SOIL STOCKPILE AREA				
CLEAR & GRUB LIGHT VEGETATION	2.75	AC	3825.00	10,519
GRADE	4500	CY	2.00	9,000
GRAVEL - 12" THICK	13310	SY	3.50	46,585
6" SAND	2200	CY	10.00	22,000
INCINERATOR SITE				
CLEAR & GRUB LIGHT VEGETATION	2	AC	3825.00	7,650
GRADE	3300	CY	2.00	6,600
GRAVEL - 12" THICK	9680	SY	3.50	33,880
DECON PAD	1	LS	10000.00	10,000
LABORER (2 MEN*10 DAY/MAN*8 HR/DAY)	160	MNHR	30.50	4,880
CARPENTER (2 MEN*10 DAY/MAN*8 HR/DAY)	160	MNHR	39.00	6,240
ELECTRICIAN (2 MEN*10 DAY/MAN*8 HR/DAY	160	MNHR	42.50	6,800
SITE SUPERINTENDANT (30 MON*210 HR/MON	6300	MNHR	62.25	392,175
FOREMAN (30 MON * 210 HR/MON)	6300	MNHR	51.75	326,025
CLERK/TYPIST (30 MON * 168 HR/MON)	5040	MNHR	26.00	131,040
UNDEVELOPED DESIGN DETAILS ~20%				874,368
TOTAL SITE PREPARATION AND MOB/DEMOB				$5,244,000

DATE:03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION WP-10 ON-SITE INCINERATION
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION WP-10 ON-SITE INCINERATION
CONTAMINATED SOIL DELINEATION & DIAPHRAGM WALL CONSTRUCT

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
CONTAMINATED SOIL DELINEATION				
DRILLING	63	BRG	2915.00	$183,645
ON-SITE ANALYSIS	55	DAY	935.00	51,425
OFF-SITE ANALYSIS	77	SMPL	900.00	69,300
UNDEVELOPED DESIGN DETAILS ~20%				60,630
TOTAL CONTAMINATED SOIL DELINEATION				$365,000
DIAPHRAGM WALL CONSTRUCTION				
VENDOR'S QUOTE	1	LS	8750000.00	$8,750,000
UNDEVELOPED DESIGN DETAILS ~20%				1,750,000
TOTAL DIAPHRAGM WALL CONSTRUCTION				$10,500,000

DATE:03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION WP-10 ON-SITE INCINERATION
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

JOB # 6853-09

ESTIMATOR: P. R. MARTIN

OPTION WP-10 ON-SITE INCINERATION

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
EXCAVATE CLEAN SOIL				
BACKHOE & OPERATOR	3	DAY	3000.00	$9,000
DUMP TRUCK & DRIVER (5 EA)	15	DAY	650.00	9,750
LABORER (2 EA)	48	HR	30.00	1,440
DOZER & OPERATOR	3	DAY	1450.00	4,350
EXCAVATE CONTAMINATED SOIL				
CLAM SHELL (2 SHIFT/DAY)	100	SHIFT	1125.00	112,500
DUMP TRUCK & DRIVER (2 EA, 2 SHIFT	200	SHIFT	650.00	130,000
LABORER (4 EA, 2 SHIFT/DAY)	3200	HR	30.00	96,000
SCREEN (2 SHIFT/DAY)	100	SHIFT	175.00	17,500
FRONT END LOADER (2 SHIFT/DAY)	100	SHIFT	750.00	75,000
FRONT END LOADER (3 SHIFT/DAY)	150	SHIFT	700.00	105,000
TOTAL PER PIT				$560,540 x3
TOTAL FOR 3 PITS				$1,681,620
UNDEVELOPED DESIGN DETAILS ~20%				336,380
TOTAL EXCAVATION OF CONTAMINATED SOIL				$2,018,000

DATE: 03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION WP-10 ON-SITE INCINERATION
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

JOB # 6853-09

ESTIMATOR: P. R. MARTIN

OPTION WP-10 ON-SITE INCINERATION

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
BACKFILL				
FRONT END LOADER - 3 CY	25	DAY	1250.00	$31,250
DUMP TRUCK & DRIVER (4 EA)	100	DAY	650.00	65,000
BORROW MATERIAL	800	CY	8.00	6,400
LABORER (2 EA)	400	HR	30.00	12,000
SEED, FERTILIZE, MULCH	0.25	AC	2000.00	500
	TOTAL PER PIT			$115,150 x3
	TOTAL FOR 3 PITS			$345,450
UNDEVELOPED DESIGN DETAILS ~20%				69,550
TOTAL BACKFILL				$415,000

DATE: 03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION WP-10 ON-SITE INCINERATION
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION WP-10 ON-SITE INCINERATION

ANNUAL O&M DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
INCINERATION				
PERMITTING	1	LS	200000.00	$200,000
INCINERATION FEE	109800	TON	200.00	21,960,000
ANALYTICAL	750	SMPL	900.00	675,000
SECONDARY WASTE DISPOSAL				
TRANSPORTATION	366	LOAD	513.00	187,758
LINER FEE	366	LOAD	50.00	18,300
DISPOSAL	10980	TON	142.50	1,564,650
UNDEVELOPED DESIGN DETAILS ~20%				4,921,292
TOTAL INCINERATION				$29,527,000
TOTAL EXCAVATION				2,018,000
TOTAL BACKFILL				415,000
TOTAL O&M COSTS				$31,960,000

THESE ITEMS TAKE PLACE OVER A 1.5 YEAR PERIOD. THIS PERIOD BEGINS 1 YEAR AFTER THE START OF CONSTRUCTION. THIS ONE YEAR PERIOD INCLUDES PERMITTING, TRIAL BURNS, AND DIAPHRAGM WALL CONSTRUCTION.

ANNUAL O&M COSTS $21,307,000

DATE: 03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION WP-11 IN-SITU VACUUM EXTRACTION, SOIL WASHING, AND COMPOSTING
LOCATION: PROPELLANT BURNING GROUND WASTE PITS
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION WP-11 IN-SITU VACUUM EXTRACTION, SOIL WASHING, AND COMPOSTING
COST SUMMARY TABLE

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
DIRECT COST OPTION WP-11 IN-SITU VACUUM EXTRACTION, SOIL WASHING, AND COMPOSTING				
TREATABILITY TESTING				$126,000
CONTAMINATED SOIL DELINEATION				365,000
SITE PREPARATION AND MOB/DEMOB				2,331,000
IN-SITU VACUUM EXTRACTION SYSTEM CONSTRUCTION				103,000
IN-SITU VACUUM EXTRACTION SYSTEM OPERATION				20,000
DIAPHRAGM WALL CONSTRUCTION				10,500,000
EXCAVATE CONTAMINATED SOIL				2,018,000
SOIL WASHING				9,414,000
COMPOSTING				1,636,000
BACKFILL				415,000
TOTAL DIRECT COST OPTION WP-11 IN-SITU VACUUM EXTRACTION, SOIL WASHING, AND COMPOSTING				$26,928,000
INDIRECT COST OPTION WP-11 IN-SITU VAC EXTRACTION, SOIL WASHING, AND COMPOSTING				
HEALTH AND SAFETY			5.00%	$1,346,000
LEGAL, ADMIN, PERMITTING			5.00%	1,346,000
ENGINEERING			10.00%	2,693,000
SERVICES DURING CONSTRUCTION			10.00%	2,693,000
TOTAL INDIRECT COST OPTION WP-11 IN-SITU VACUUM EXTRACTION, SOIL WASHING, AND COMPOSTING				$8,078,000
TOTAL CAPITAL (DIRECT + INDIRECT) COST				$35,006,000
OPERATING AND MAINTENANCE COSTS				
COMPOSTING OPERATING AND MAINTENANCE COSTS				$1,052,000
TOTAL PRESENT WORTH OF COMPOSTING O&M COSTS (5% FOR 3.5 YEARS)				$3,303,000
TOTAL COST OPTION WP-11 IN-SITU VACUUM EXTRACTION, SOIL WASHING, AND COMPOSTING				$38,309,000

DATE:03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION WP-11 IN-SITU VACUUM EXTRACTION, SOIL WASHING, AND COMPOSTING
JOB # 6853-09
LOCATION: PROPELLANT BURNING GROUND WASTE PITS
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION WP-11 IN-SITU VACUUM EXTRACTION, SOIL WASHING, AND COMPOSTING
SITE PREPARATION AND MOB/DEMOB

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
EQUIPMENT (IN OR OUT)				
FRONT END LOADER	8	EA	520.00	$4,160
DUMP TRUCKS	22	EA	260.00	5,720
BACKHOE	6	EA	520.00	3,120
DOZER	4	EA	1000.00	4,000
OFFICE TRAILER	24	MON	155.00	3,720
STORAGE TRAILER (2 EA)	48	MON	155.00	7,440
TRAILER SET-UP & DELIVERY, REMOVAL	3	EA	310.00	930
TOILET (2EA*2 YR/EA*52WK/YR)	208	WK	25.00	5,200
WATER CLR (2EA*2 YR/EA*52WK/YR)	208	WK	25.00	5,200
WATER (208 WK * 5 DAY/WK)	1040	DAY	15.00	15,600
TELEPHONE SERVICE	24	MON	520.00	12,480
ELECTRICAL HOOK-UP	1	LS	2500.00	2,500
ELECTRICAL POWER	24	MON	300.00	7,200
PICK-UP (2 EA * 24 MON/EA)	48	MON	1035.00	49,680
OFFICE EQUIPMENT	24	MON	1035.00	24,840
PUMPS, TOOLS MINOR EQUIPMENT	1	LS	5000.00	5,000
STAGING AREA				
TEMPORARY COVERED AREA	3200	SF	35.00	112,000
CLEAR & GRUB LIGHT VEGETATION	1	AC	3825.00	3,825
GRADE	1650	CY	2.00	3,300
GRAVEL - 12" THICK	4840	SY	3.50	16,940
PARKING AREA				
CLEAR & GRUB LIGHT VEGETATION	0.5	AC	3825.00	1,913
GRADE	825	CY	2.00	1,650
GRAVEL - 12" THICK	2420	SY	3.50	8,470
UNTREATED SOIL STOCKPILE AREA				
CLEAR & GRUB LIGHT VEGETATION	0.25	AC	3825.00	956
GRADE	400	CY	2.00	800
EARTH BERM FROM GRADED SOIL	400	CY	2.00	800
GRAVEL - 12" THICK	1210	SY	3.50	4,235
40 MIL LINER	1210	SY	6.00	7,260
6" SAND	200	CY	10.00	2,000
SUMP	1	LS	2500.00	2,500
DRAIN PIPE	200	LF	5.00	1,000
TOTAL THIS PAGE				$324,439

DATE: 03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION WP-11 IN-SITU VACUUM EXTRACTION,
SOIL WASHING, AND COMPOSTING
LOCATION: PROPELLANT BURNING GROUND WASTE PITS
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION WP-11 IN-SITU VACUUM EXTRACTION, SOIL WASHING, AND COMPOSTING
SITE PREPARATION AND MOB/DEMOB

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
TOTAL PAGE 2				$324,439
TREATED SOIL STOCKPILE AREA				
CLEAR & GRUB LIGHT VEGETATION	2.75	AC	3825.00	10,519
GRADE	4500	CY	2.00	9,000
GRAVEL - 12" THICK	13310	SY	3.50	46,585
6" SAND	2200	CY	10.00	22,000
DECON PAD	1	LS	10000.00	10,000
SOIL WASHING SITE				
CLEAR & GRUB LIGHT VEGETATION	1.5	AC	3825.00	5,738
GRADE	2400	CY	2.00	4,800
EARTH BERM FROM GRADED SOIL	2400	CY	2.00	4,800
GRAVEL - 12" THICK	7260	SY	3.50	25,410
40 MIL LINER	7260	SY	6.00	43,560
6" SAND	1200	CY	10.00	12,000
SUMP	1	LS	5000.00	5,000
DRAIN PIPE	400	LF	5.00	2,000
SLUDGE STOCKPILE AREA				
CLEAR & GRUB LIGHT VEGETATION	0.5	AC	3825.00	1,913
GRADE	800	CY	2.00	1,600
ASPHALT PAVING - 4" THICK	2420	SY	11.00	26,620
ASPHALT CURB - 12"Wx6"H	600	LF	2.50	1,500
TEMPORARY STRUCTURE	22000	SF	25.00	550,000
TOTAL THIS PAGE				$1,107,483

DATE: 03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION WP-11 IN-SITU VACUUM EXTRACTION, SOIL WASHING, AND COMPOSTING
JOB # 6853-09
LOCATION: PROPELLANT BURNING GROUND WASTE PITS
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION WP-11 IN-SITU VACUUM EXTRACTION, SOIL WASHING, AND COMPOSTING
SITE PREPARATION AND MOB/DEMOB

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
TOTAL PAGE 3				$1,107,483
MIXING AREA				
CLEAR & GRUB LIGHT VEGETATION	0.5	AC	3825.00	1,913
GRADE	800	CY	2.00	1,600
ASPHALT PAVING - 4" THICK	2420	SY	7.50	18,150
ASPHALT CURB - 12"Wx6"H	600	LF	2.50	1,500
COMPOSTING AREA				
CLEAR & GRUB LIGHT VEGETATION	3	AC	3825.00	11,475
GRADE	4950	CY	2.00	9,900
GRAVEL - 6" THICK	14520	SY	1.75	25,410
ASPHALT PAD	85000	SF	0.80	68,000
LABORER (2 MEN*10 DAY/MAN*8 HR/DAY)	160	MNHR	30.50	4,880
CARPENTER (2 MEN*10 DAY/MAN*8 HR/DAY)	160	MNHR	39.00	6,240
ELECTRICIAN (2 MEN*10 DAY/MAN*8 HR/DAY	160	MNHR	42.50	6,800
SITE SUPERINTENDANT (24 MON*210 HR/MON	5040	MNHR	62.25	313,740
FOREMAN (24 MON * 210 HR/MON)	5040	MNHR	51.75	260,820
CLERK/TYPIST (24 MON * 168 HR/MON)	4032	MNHR	26.00	104,832
UNDEVELOPED DESIGN DETAILS ~20%				388,258
TOTAL SITE PREPARATION AND MOB/DEMOB				$2,331,000

DATE: 03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION WP-11 IN-SITU VACUUM EXTRACTION,
SOIL WASHING, AND COMPOSTING
JOB # 6853-09

LOCATION: PROPELLANT BURNING GROUND WASTE PITS
BADGER ARMY AMMUNITION PLANT

ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION WP-11 IN-SITU VACUUM EXTRACTION, SOIL WASHING, AND COMPOSTING

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
TREATABILITY TESTING				
COMPOSTING	1	LS	30000.00	$30,000
SVE PILOT TEST	1	LS	45000.00	45,000
SOIL WASHING	1	LS	30000.00	30,000
UNDEVELOPED DESIGN DETAILS ~20%				21,000
TOTAL TREATABILITY TESTING				$126,000
CONTAMINATED SOIL DELINEATION				
DRILLING	63	BRG	2915.00	$183,645
ON-SITE ANALYSIS	55	DAY	935.00	51,425
OFF-SITE CONFIRMATORY ANALYSIS	77	SMPL	900.00	69,300
UNDEVELOPED DESIGN DETAILS ~20%				60,630
TOTAL CONTAMINATED SOIL DELINEATION				$365,000

DATE:03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION WP-11 IN-SITU VACUUM EXTRACTION, SOIL WASHING, AND COMPOSTING
JOB # 6853-09
LOCATION: PROPELLANT BURNING GROUND WASTE PITS
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION WP-11 IN-SITU VACUUM EXTRACTION, SOIL WASHING, AND COMPOSTING

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
IN-SITU VACUUM EXTRACTION SYSTEM CONSTRUCTION				
EXTRACTION WELL	2	EA	8500.00	$17,000
VADOSE MONITORING WELLS	6	EA	8000.00	48,000
PIPE & FITTINGS	1	LS	1000.00	1,000
BLOWER RENTAL	1	LS	1634.00	1,634
TEMPORARY BUILDING	1	LS	10000.00	10,000
CARBON ADSORBER RENTAL				
FIRST MONTH	2	EA	1995.00	3,990
ADDITIONAL MONTHS FOR 2 EA	5	MON	590.00	2,950
CARBON REACTIVATION	1	LS	200.00	200
ANALYTICAL	1	LS	1425.00	1,425
UNDEVELOPED DESIGN DETAILS ~20%				16,801
TOTAL IN-SITU VACUUM EXTRACTION SYSTEM CONSTRUCTION				$103,000
IN-SITU VACUUM EXTRACTION SYSTEM OPERATION				
DAILY MONITORING	180	HR	30.00	$5,400
WEEKLY MONITORING	48	HR	75.00	3,600
ANALYTICAL	144	SMPL	50.00	7,200
POWER - 5 HP	16300	KWHR	0.04	652
UNDEVELOPED DESIGN DETAILS ~20%				3,148
TOTAL IN-SITU VACUUM EXTRACTION SYSTEM OPERATION				$20,000

DATE:03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION WP-11 IN-SITU VACUUM EXTRACTION, SOIL WASHING, AND COMPOSTING
JOB # 6853-09
LOCATION: PROPELLANT BURNING GROUND WASTE PITS
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION WP-11 IN-SITU VACUUM EXTRACTION, SOIL WASHING, AND COMPOSTING

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
DIAPHRAGM WALL CONSTRUCTION				
VENDOR'S QUOTE	1	LS	8750000.00	$8,750,000
UNDEVELOPED DESIGN DETAILS ~20%				1,750,000
TOTAL DIAPHRAGM WALL CONSTRUCTION				$10,500,000
EXCAVATE CLEAN SOIL				
BACKHOE & OPERATOR	3	DAY	3000.00	$9,000
DUMP TRUCK & DRIVER (5 EA)	15	DAY	650.00	9,750
LABORER (2 EA)	48	HR	30.00	1,440
DOZER & OPERATOR	3	DAY	1450.00	4,350
EXCAVATE CONTAMINATED SOIL				
CLAM SHELL (2 SHIFT/DAY)	100	SHIFT	1125.00	112,500
DUMP TRUCK & DRIVER (2 EA, 2 SHIFT	200	SHIFT	650.00	130,000
LABORER (4 EA, 2 SHIFT/DAY)	3200	HR	30.00	96,000
SCREEN (2 SHIFT/DAY)	100	SHIFT	175.00	17,500
FRONT END LOADER (2 SHIFT/DAY)	100	SHIFT	750.00	75,000
FRONT END LOADER (3 SHIFT/DAY)	150	SHIFT	700.00	105,000
TOTAL PER PIT				$560,540 x3
TOTAL FOR 3 PITS				$1,681,620
UNDEVELOPED DESIGN DETAILS ~20%				336,380
TOTAL EXCAVATION OF CONTAMINATED SOIL				$2,018,000

DATE: 03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION WP-11 IN-SITU VACUUM EXTRACTION, SOIL WASHING, AND COMPOSTING

JOB # 6853-09

LOCATION: PROPELLANT BURNING GROUND WASTE PITS
BADGER ARMY AMMUNITION PLANT

ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION WP-11 IN-SITU VACUUM EXTRACTION, SOIL WASHING, AND COMPOSTING

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
BACKFILL				
FRONT END LOADER - 3 CY	25	DAY	1250.00	$31,250
DUMP TRUCK & DRIVER (4 EA)	100	DAY	650.00	65,000
BORROW MATERIAL	800	CY	8.00	6,400
LABORER (2 EA)	400	HR	30.00	12,000
SEED, FERTILIZE, MULCH	0.25	AC	2000.00	500
TOTAL PER PIT				$115,150 x3
TOTAL FOR 3 PITS				$345,450
UNDEVELOPED DESIGN DETAILS ~20%				69,550
TOTAL BACKFILL				$415,000
SOIL WASHING				
SOIL WASHING FEE	73200	CY	100.00	$7,320,000
ANALYTICAL	700	SMPL	900.00	630,000
UNDEVELOPED DESIGN DETAILS ~20%				1,464,000
TOTAL SOIL WASHING				$9,414,000

DATE:03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION WP-11 IN-SITU VACUUM EXTRACTION,
SOIL WASHING, AND COMPOSTING
JOB # 6853-09

LOCATION: PROPELLANT BURNING GROUND WASTE PITS
BADGER ARMY AMMUNITION PLANT

ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION WP-11 IN-SITU VACUUM EXTRACTION, SOIL WASHING, AND COMPOSTING

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
COMPOSTING CONTAMINATED SLUDGE FROM SOIL WASHING				
WINDROW STRUCTURES				
PURCHASE	4	EA	261670.00	$1,046,680
EQUIPMENT STORAGE BLDG	1	EA	20000.00	20,000
DELIVERY	1	LS	12000.00	12,000
SOIL TURNING EQUIPMENT PURCHASE	1	EA	180000.00	180,000
FRONT END LOADER PURCHASE	1	EA	120000.00	120,000
HAUL TRUCK PURCHASE	1	EA	80000.00	80,000
SALVAGE VALUE	-25.00%		380000.00	(95,000
UNDEVELOPED DESIGN DETAILS ~20%				272,320
TOTAL COMPOSTING				$1,636,000

DATE:03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION WP-11 IN-SITU VACUUM EXTRACTION,
SOIL WASHING, AND COMPOSTING
LOCATION: PROPELLANT BURNING GROUND WASTE PITS
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION WP-11 IN-SITU VACUUM EXTRACTION, SOIL WASHING, AND COMPOSTING

POST CLOSURE MAINTENANCE DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
COMPOSTING O&M COSTS				
EQUIPMENT - FUEL, ELECTRICITY, MAINTENANCE	52	WK	4000.00	$208,000
LABOR - 6 EA	52	WK	5500.00	286,000
AMENDMENT	5500	TON	50.00	275,000
ANALYTICAL	120	SMPL	900.00	108,000
UNDEVELOPED DESIGN DETAILS ~20%				175,000
TOTAL COMPOSTING O&M COSTS				$1,052,000

APPENDIX D.3

MATERIAL USAGE: SOIL ALTERNATIVES

PROPELLANT BURNING GROUND

PROJECT	COMP. BY	JOB NO.
PROPELLANT BURNING GROUND MODIFIED IN SITU S/S QUANTITIES (PBG-SS6)	JSM	6853-09
	CHK. BY	DATE 6/23/94

IN SITU S/S INSIDE RACETRACK AND AT CONTAMINATED WASTE AREA

RACETRACK AREA:

- ASSUME RACETRACK IN-FIELD AREA ~ 200' x 500'
  $\Rightarrow$ 100,000 FT^2
  ~ 11,111 YD^2
- ASSUME IN SITU S/S TO 2' BGS
  $\Rightarrow$ 11,111 YD^2 x 2/3 YD
  ~ 7,400 YD^3

CONTAMINATED WASTE AREA:

- ASSUME AREA ~ 450' x 600' $\Rightarrow$ 270,000 FT^2
  = 30,000 YD^2
- ASSUME IN SITU S/S TO 2' BGS
  $\Rightarrow$ 30,000 YD^2 x 2/3 YD
  = 20,000 YD^3

$\Rightarrow$ GRAND TOTAL FOR IN SITU S/S INSIDE RACETRACK AT AT CONTAMINATED WASTE AREA =
7,400 YD^3 + 20,000 YD^3 = 27,400 YD^3

EXCAVATION, PLACEMENT, AND TREATMENT OF SOIL FROM THE BURNING PADS AREA, BURNING PLATES AREA, AND REFUSE PITS

OUTSIDE RACETRACK:

- ASSUME AREAS WHERE PB IN SURFACE SOIL EXCEEDS 1,000 PPM SHOULD BE EXCAVATED TO 4' BGS (FROM FIGURE 3-9)
  $\Rightarrow$ 100' x 150' + 125' x 150' + 50' x 125' = 40,000 FT^2
  $\Rightarrow$ 40,000 FT^2 x 4 FT = 160,000 FT^3
  ~ 6,000 YD^3
- REMAINDER OF SOIL > 30 PPM OUTSIDE RACETRACK
  $\Rightarrow$ ((200' x 700') + (100' x 700')) − 40,000 FT^2
  = 170,000 FT^2
  $\Rightarrow$ 170,000 FT^2 x 2 FT = 340,000 FT^3
  ~ 12,600 YD^3

PROJECT	COMP. BY	JOB NO.
PROPELLANT BURNING GROUNDS MODIFIED IN SITU S/S QUANTITIES (PBG-SS6)	JSM	6853-09
	CHK. BY	DATE 6/23/94

• REFUSE PITS 1, 2, AND 3 (FROM RI DATA & RGs)

REFUSE PIT 1 = 20' DIA. x 20' DEEP
= 6,283 FT^3
~ 233 YD^3

REFUSE PIT 2 = 20' DIA. x 25' DEEP
= 7,854 FT^3
~ 290 YD^3

REFUSE PIT 3 = 20' DIA. x 15' DEEP
= 4,712 FT^3
~ 175 YD^3

TOTAL QTY FROM REFUSE PITS
233 YD^3 + 290 YD^3 + 175 YD^3 = 698 YD^3
~ 700 YD^3

⇒ GRAND TOTAL FOR EXCAVATION, PLACEMENT, AND TREATMENT OF SOIL FROM OUTSIDE RACETRACK
= 6,000 YD^3 + 12,600 YD^3 + 700 YD^3
= 19,300 YD^3

AVERAGE HEIGHT OF STABILIZED SOIL PILE INSIDE RACETRACK ASSUMING 50% SWELL FACTOR:

19,300 YD^3 x 1.5 OVER 11,111 YD^2 = 2.6 YD
~ 8 FT

SOIL COVER CONSTRUCTION

RACETRACK:

• ASSUME 300' x 700' = 210,000 FT^2 AREA

⇒ FOR 2-FOOT DEPTH OF BORROW
210,000 FT^2 x 2 FT = 420,000 FT^3
~ 15,560 YD^3
x 1.33 (SWELL FACTOR)
~ 20,700 YD^3

FORM 00.01 REV. 4/81 ABB Environmental Services, Inc.

PROJECT	COMP. BY	JOB NO.
PROPELLANT BURNING GROUND MODIFIED IN SITU S/S QUANTITIES (PBG-SS6)	JSM	6853-09
	CHK. BY	DATE 6/23/94

⇒ FOR 6 INCHES OF TOPSOIL

$210{,}000\ FT^2 \times 0.5\ FT = 105{,}000\ FT^3$

$\sim 3{,}890\ YD^3$

$\times\ 1.15$ (SWELL FACTOR)

$\sim \underline{4{,}500\ YD^3}$

CONTAMINATED WASTE AREA:

- ASSUME $450' \times 600' = 270{,}000\ FT^2$

⇒ FOR 2-FOOT DEPTH OF BORROW

$270{,}000\ FT^2 \times 2\ FT = 540{,}000\ FT^3$

$= 20{,}000\ YD^3$

$\times\ 1.33$ (SWELL FACTOR)

$\sim \underline{27{,}000\ YD^3}$

⇒ FOR 6 INCHES OF TOPSOIL

$270{,}000\ FT^2 \times 0.5\ FT = 135{,}000\ FT^3$

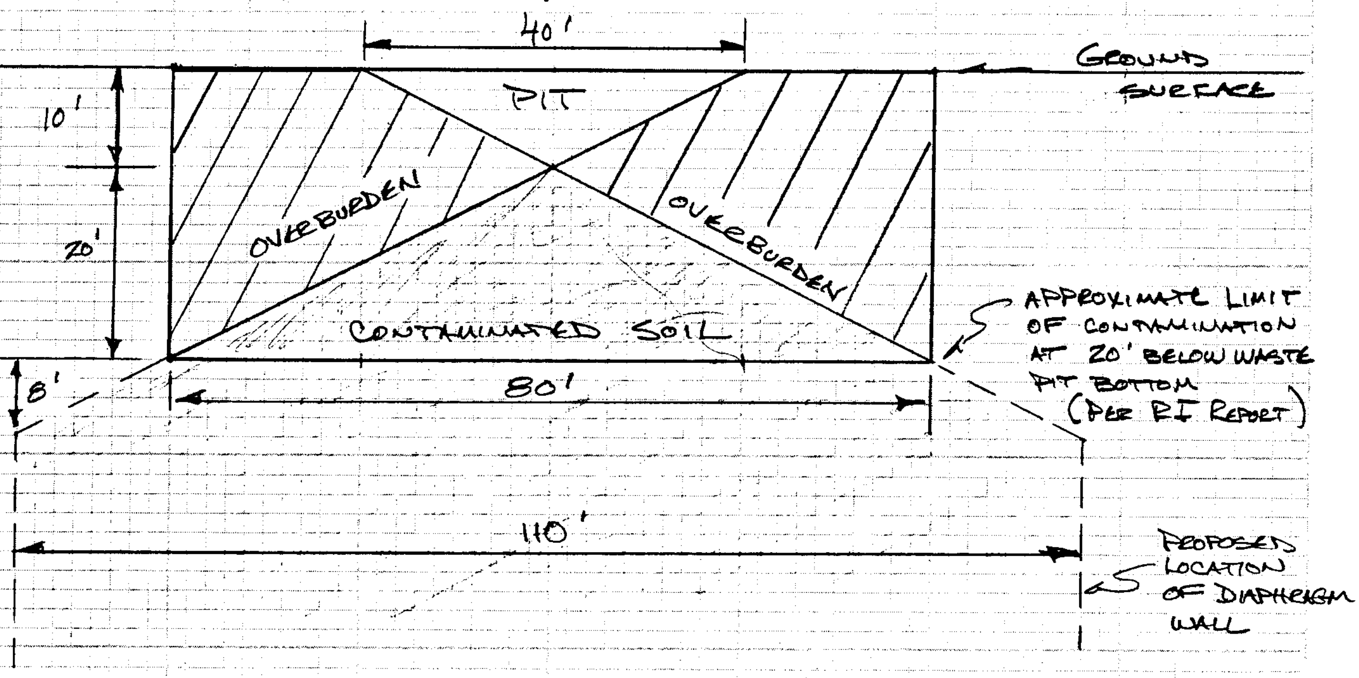
$= 5{,}000\ YD^3$

$\times\ 1.15$ (SWELL FACTOR)

$\sim \underline{5{,}800\ YD^3}$

PROJECT BAAP FS VOLUME CALCS FOR CONTAMINATED WASTE PIT SOIL	COMP. BY JSM CHK BY [initials]	JOB NO. 6853-09 DATE 4/30/93

CALC 1: VOLUME OF CONTAMINATED SOIL FROM WASTE PIT BOTTOM DOWN TO 20' BELOW WASTE PIT BOTTOM AND LATERALLY TO THE LIMIT OF CONTAMINATION.



VOLUME = CONE $\Rightarrow$ $V = \frac{1}{3}\pi R^2 h$

$$= \frac{1}{3}\pi\, 40^2(20) = 33{,}510 \text{ FT}^3$$

$$= 1{,}241 \text{ YD}^3 \approx \underline{1{,}250 \text{ YD}^3}$$

CALC 2: VOLUME OF CONTAMINATED SOIL FROM WASTE PIT BOTTOM DOWN TO VERTICAL LIMIT OF CONTAMINATION ($\approx$ 100' BGS) AND LATERALLY 55' FROM CENTER OF PIT.

VOLUME = CONE + CYLINDER $\Rightarrow$ $V = \frac{1}{3}\pi R^2 h + \pi R^2 h$

$$= \frac{1}{3}\pi\, 55^2(28) + \pi\, 55^2 (\cancel{60})\ 62$$

$$= 88{,}700 \text{ FT}^3 + \cancel{570{,}200}\ 589{,}200 \text{ FT}^3$$

$$= \cancel{658{,}900}\ 677{,}900 \text{ FT}^3$$

$$= \cancel{24{,}403 \text{ YD}^3} \approx \cancel{24{,}400}\ 25{,}100 \text{ yd}^3 \text{ YD}^3$$

25,108 yd³

NOTE: FOR PURPOSES OF THE FS, A VOLUME OF 24,400 YD³ WAS USED. JSM

PROJECT BAAP FS MASS CALCS FOR CONTAMINANTS IN WASTE PIT SOIL (TO 20' BELOW PIT BOTTOM)	COMP. BY JSM CHK. BY SNR	JOB NO. 6853-09 DATE 7/8/93

MASS OF CONTAMINANTS IN WASTE PIT SOIL DOWN TO 20' BELOW PIT BOTTOMS:

VERTICALLY: DNT CONCENTRATIONS RANGE FROM 10,000 PPM TO 280,000 PPM

LATERALLY: ASSUME MAJORITY OF CONTAMINANTS ARE WITHIN 20' RADIUS OF PIT CENTER

ASSUME AVERAGE DNT CONCENTRATION EQUALS 20,000 PPM

ASSUME HEAVILY CONTAMINATED SOIL VOLUME = $\pi/3 \times 20^2 \times 20 \approx 8,380\ FT^3$

TOTAL = $8,380\ FT^3/PIT \times 3\ PITS$

$= 25,140\ FT^3$ ✓

ASSUME SOIL MASS = $110\ lb/FT^3$

$\Rightarrow$ TOTAL SOIL MASS = $25,140\ FT^3 \left(\frac{110\ lb}{FT^3}\right)$

$= 2,765,400\ lbs$

CONVERTING TO GRAMS:

$2,765,400\ lbs \left(\frac{454\ g}{lb}\right) \approx 1.26 \times 10^9\ g$ ✓

$\Rightarrow$ MASS OF DNTs $= 1.26 \times 10^9\ g \times \frac{0.020\ g}{g}$

$= 2.52 \times 10^7\ g$

$= 55,506\ lbs$

$\approx 55,500\ lbs$ ✓

FORM 00.01 REV. 4/81

ABB Environmental Services, Inc.

PROJECT BAAP FS ALTERNATIVES PBG-WP7 AND WP-11 CONCEPTUAL DESIGN FOR IN SITU VACUUM EXTRACTION	COMP. BY JSM	JOB NO. 6853-09
	CHK. BY	DATE 6/7/94

PURPOSE: ESTIMATE THE SIZE OF VACUUM EXTRACTION AND TREATMENT EQUIPMENT FOR ~~THE CAPPED~~ JSM WASTE PITS.

REFERENCE: "A PRACTICAL APPROACH TO THE DESIGN, OPERATION, AND MONITORING OF IN SITU SOIL-VENTING SYSTEMS" JOHNSON, ET. AL., SPRING 1990 GWMR

I. ESTIMATE VAPOR EXTRACTION FLOW PER WELL & NUMBER OF WELLS/PIT

FIGURE 5 OF THE REFERENCE PROVIDES PREDICTED STEADY-STATE FLOW RATES (PER UNIT WELL SCREEN THICKNESS) FOR A RANGE OF SOIL PERMEABILITIES AND APPLIED VACUUMS. THE FIGURE IS SPECIFIC TO A 2" WELL WITH A RADIUS OF INFLUENCE OF 40'.

FROM REVIEW OF THE BORING LOG FOR PBB-91-06 (WASTE PIT No. 1), SOILS RANGE FROM VERY FINE SANDS TO GRAVELS. A SOIL PERMEABILITY OF 10 DARCY WAS SELECTED (REPRESENTATIVE OF MEDIUM SANDS). PER THE REFERENCE, TYPICAL VACUUM WELL PRESSURES RANGE FROM 0.95 - 0.90 ATM. A VALUE OF 0.95 ATM WAS SELECTED (TO BE CONSERVATIVE).

FROM FIGURE 5 (ASSUMING $k = 10$ DARCY & $P_w = 0.95$ ATM)

$$\frac{Q^*}{H} \approx 1.1 \text{ SCFM/FT}$$ (FLOW RATE PER UNIT WELL SCREEN THICKNESS)

$$\frac{Q^*}{H} = \frac{Q}{H(P_w/P_{ATM})} \approx 1.1$$

$$\Rightarrow \frac{Q}{H(0.95)} \approx 1.1$$

$$\Rightarrow \frac{Q}{H} \approx \underline{\underline{1.0}} \text{ SCFM/FT}$$

BECAUSE 4" DIAMETER WELLS ARE ASSUMED FOR CONCEPTUAL DESIGN PURPOSES, AND EACH WELL IS ASSUMED TO HAVE A RADIUS OF INFLUENCE OF 40 FEET, A CORRECTION FACTOR OF 1.15 IS APPLIED TO THE ABOVE RESULT.

$$\Rightarrow \frac{Q}{H} = 1.0 \times 1.15$$
$$= 1.15 \text{ SCFM/FT}$$

FROM CONTAMINATION PROFILES CONTAINED IN THE RI REPORT, THE VOC CONTAMINATION EXTENDS TO 100 FEET BGS. ~~HOWEVER, THE CONTAMINATED ZONE WILL HAVE BEEN EXCAVATED TO A DEPTH OF 30' BGS.~~ JSM THEREFORE, THE CONTAMINATED ZONE IS 10' BGS TO 100' BGS, OR 90' THICK.

$$\Rightarrow Q = 1.15 \text{ SCFM/FT} \times 90 \text{ FT} = \underline{103.5 \text{ SCFM}}$$

(2)

PROJECT BAAP FS ALTERNATIVE PBG-WP7 AND WP-11 CONCEPTUAL DESIGN FOR IN SITU VACUUM EXTRACTION	COMP. BY BSM	JOB NO. 6853-09
	CHK. BY	DATE 6/7/94

II. ESTIMATE MASS OF VOCs IN SOIL TO BE REMEDIATED BY VACUUM EXTRACTION

BASED ON C6H6 & TRCLE VERTICAL CONCENTRATION PROFILES PROVIDED IN THE RI REPORT.

	DEPTH (FT BGS)	CONC. RANGE (PPM)	SOIL VOLUME* (FT^3)	SOIL MASS** (Kg)	CONC. (mg/kg)	VOC MASS (Kg)
C6H6	30-37	1.0-100	8,800	440,000	1.0	0.44
	37-44	>100	8,000	440,000	100	44
	44-75	1.0-100	39,000	1,950,000	1.0	1.95
	75-112	ND**-1.0	46,500	2,325,000	0.1	0.23
TRCLE	30-36	1.0-10	7,540	377,000	1.0	0.38
	36-54	>10	22,600	1,130,000	10	11.3
	54-80	1.0-10	32,700	1,635,000	1.0	1.64
	110-112	ND**-1.0	2,500	125,000	0.23	0.029
						60 Kg

* SOIL VOLUME CALCULATED BY π (20' RADIUS)^2 x DEPTH INTERVAL
** ND FOR C6H6 & TRCLE WAS 0.1 PPM & 0.23 PPM, RESPECTIVELY
*** ASSUMED SOIL BULK DENSITY = 50 Kg/FT^3

⟹ TOTAL VOC MASS IS APPROXIMATELY 60 Kg, COMPRISED OF APPROXIMATELY 46.6 Kg OF C6H6 AND 13.4 Kg OF TRCLE.

III. ASSUMING THAT REMEDIATION BY VACUUM EXTRACTION IS TO BE COMPLETED IN 6 MONTHS, THE FOLLOWING AVERAGE CONCENTRATION REACHING THE TREATMENT SYSTEM IS CALCULATED:

$$60\ Kg / 183\ DAYS \times 1\ DAY/1{,}440\ MIN \times 1/100\ FT^3/MIN \times 35.31\ FT^3/m^3 \times 10^6\ mg/Kg = \underline{80.4\ mg/m^3}$$

PER PIT

PROJECT	COMP. BY	JOB NO.
PROPELLANT BURNING GROUND (PBG-WPS) COMPOST FACILITY OPERATING PERIOD & AMENDMENT RQMNTS	JSM	6853-09
	CHK. BY	DATE 7/12/94

ASSUMPTIONS

REFERENCES: ROY F. WESTON STUDIES CONDUCTED FOR USAEC

- SOIL VOLUME = 4,000 YD^3
- BATCH OPERATION
- 45 DAYS COMPOSTING PER BATCH
- 15 DAYS MOB/DEMOB PER BATCH
- 4 TEMPORARY STRUCTURES
- 2 WINDROWS / STRUCTURE / BATCH
- 20 % SOIL LOADING
- 500 YD^3 / WINDROW $\Rightarrow$ 100 YD^3 CONTAM SOIL / WINDROW

TREATED SOIL PER BATCH:

$$4 \text{ STRUCTURES} \times 2 \frac{\text{WINDROWS}}{\text{STRUCTURE}} \times \frac{100 \text{ YD}^3}{\text{WINDROW}} = 800 \text{ YD}^3$$

$$\Rightarrow \frac{800 \text{ YD}^3}{\text{BATCH}}$$

NUMBER OF BATCHES:

$$\frac{4{,}000 \text{ YD}^3 \text{ CONTAM SOIL}}{800 \text{ YD}^3 / \text{BATCH}} = 5 \text{ BATCHES}$$

OPERATING TIME:

$$5 \text{ BATCHES} \times 60 \frac{\text{DAYS}}{\text{BATCH}} = 300 \text{ DAYS OF OPERATION}$$

$\Rightarrow$ ASSUME 10 MONTHS OF OPERATION

AMENDMENT:

$$\frac{400 \text{ YD}^3}{\text{WINDROW}} \times \frac{8 \text{ WINDROWS}}{\text{BATCH}} \times 5 \text{ BATCHES} = 16{,}000 \text{ YD}^3$$

DENSITY OF AMENDMENT = 950 lb/YD^3

$$\Rightarrow \frac{16{,}000 \text{ YD}^3 \times 950 \text{ lb/YD}^3}{2000 \text{ lbs/TON}} = 7{,}600 \text{ TONS}$$

PROJECT BAAP FS INFILTRATION RATE FOR SOIL FLUSHING	COMP. BY JSM CHK. BY MPM	JOB NO. 6853-09 DATE 4/16/93

ESTIMATE MAXIMUM Q FOR DISCHARGE INTO INFILTRATION SYSTEM AT EACH WASTE PIT:

ASSUME:

1) VERTICAL K = 50 FT/DAY (APPROXIMATELY ONE-FIFTH THE K DETERMINED IN AQUIFER TEST AT BCW-3)
2) DOWNWARD GRADIENT = 0.1 FT/FT.
3) 110' DIAMETER LEACHING CYLINDER

USING DARCY'S LAW TO ESTIMATE Q ACROSS WATERTABLE

$Q = KIA$

$= (50 \text{ FT/DAY})(0.1 \text{ FT/FT})(9{,}500 \text{ FT}^2)$

$= 47{,}500 \text{ FT}^3/\text{DAY}$

$= \frac{47{,}500 \text{ FT}^3}{\text{DAY}} \times \frac{7.48 \text{ GALLONS}}{1 \text{ FT}^3} \times \frac{1 \text{ DAY}}{1{,}440 \text{ MINUTES}}$

$\sim$ 250 GPM

FORM 00.01 REV. 4/81

ABB Environmental Services, Inc.

PROJECT BAAP FS CONTAMINANT MASS CALCS AND SOIL FLUSHING CLEANUP CALCS FOR WASTE PITS	COMP. BY JSM CHK. BY MPM	JOB NO. 6853-09 DATE 4/16/93

REVISED 7/11/94
30% → 10% 24DNT SOLUBILITY DURING FLUSHING JSM

ESTIMATE TIME REQUIRED TO FLUSH 24DNT FROM WASTE PIT SOIL. ASSUME:

1) MAJORITY OF CONTAMINATED SOIL IS IN A 50' DIA x 90' LONG CYLINDER.

2) AVERAGE 24DNT CONCENTRATION = 5,000 μg/g

3) ~~30%~~ 10 JSM 7/11/94 OF 24DNT SOLUBILITY IS REACHED DURING FLUSHING
$\Rightarrow 0.\cancel{30}_{10} \times 240\ mg/l \sim \cancel{70}_{24}\ mg/l$ (240mg/l from RI REPORT) JSM

TOTAL SOIL MASS WITHIN CYLINDER:
$\pi (25)^2 (90) \sim 177{,}000\ FT^3$

ASSUME SOIL DENSITY = 110 lb/FT³

$\Rightarrow 177{,}000\ FT^3 \times \frac{110\ lb}{FT^3} = 19{,}470{,}000\ lbs$ ✓ $4.5359 \times 10^2\ g/lbs$

$\sim 8.8 \times 10^9\ g$ ✓

24DNT MASS WITHIN CYLINDER:
$8.8 \times 10^9\ g \times \frac{0.005\ g}{g} = 4.4 \times 10^7\ g$

$\sim \cancel{96{,}900}\ lbs$ 97,000 lbs

INFILTRATION RATE THROUGH WASTE PIT SOIL = 250 GPM
$250\ g/min \times (6.308 \times 10^{-2}) = 15.77\ l/sec \times 86400\ sec/day \approx 1{,}440{,}000\ \frac{LITERS}{DAY}$

⇒ TIME REQUIRED FOR CLEANUP
$1{,}440{,}000\ \frac{LITERS}{DAY} \times 0.0\cancel{70}_{24}\ \frac{g}{LITER} = \cancel{100{,}800}\ 34{,}560\ g/DAY$ ✓ JSM

$4.4 \times 10^7\ g / (\cancel{100{,}800}\ 34{,}560\ g/DAY) = \cancel{436}\ 1{,}273$ DAYS ✓ JSM
$\sim \cancel{440}\ 1{,}300$ DAYS

NOTE: VARYING THE PER CENT SOLUBILITY ACHIEVED DURING SOIL FLUSHING, THE TIME FOR CLEAN-UP COULD TAKE FROM 127 DAYS ✓ (ASSUMING 100% SOLUBILITY IS REACHED) TO 35 ✓ YEARS (ASSUMING 1% SOLUBILITY IS REACHED.

PROJECT	COMP. BY	JOB NO.
BAAP FS PUMP REQUIREMENTS FOR SOIL FLUSHING SYSTEM	JSM CHK. BY MPM	6853-09 DATE 5/10/93

(1) FROM BAAP WELL NO. 5 TO INFILTRATION GALLERY:

1,200 FT OF 4" PIPE

PLUS 4" HEADER PIPE (100') = 1,300 FT

$$f = 0.2083\left(\frac{100}{130}\right)^{1.85}\frac{250^{1.85}}{4^{4.8655}} = 4.1'/100' \text{ OF PIPE}$$

$\Rightarrow$ FRICTION HEAD LOSS = ~~53.3'~~ 53.5'

$\Rightarrow$ PLUS 20' FOR Δ ELEV. = 73.5 $\rightarrow$ 75 FEET

TDH = 75 FEET

(2) FROM EXTRACTION WELLS TO IRM:

- 1,040 FEET TO EXISTING IRM FACILITY SOURCE CONTROL WELL
- PLUS 5,500' (SOW-1 TO IRM) + 222' (IN IRM)

TOTAL = 6762' ≈ 6,800 FT

$$f = 0.2083\left(\frac{100}{130}\right)^{1.85}\frac{275^{1.85}}{4^{4.8655}} = 5'/100' \text{ OF PIPE}$$

(275gpm is extraction rate)

$\Rightarrow$ FRICTION HEAD LOSS = 340'

$\Rightarrow$ PLUS 60' (100-40) FOR Δ ELEV. = 400'

$\Rightarrow$ TDH = 400'

HORSEPOWER FOR (1) $\frac{(75')(250)}{(0.75)(3960)} = 6.3$ HP (BAAP NO. 5)

(assuming 75% efficiency of the pump)

(2) $\frac{(400')(275)}{(0.75)(3960)} = 37$ HP (FLUSHING SOLUTION EXTRACTION)

PROJECT	COMP. BY	JOB NO.
PROPELLANT BURNING GROUND (PBG-WP11) COMPOST FACILITY OPERATING PERIOD & AMENDMENT RQMNTS	JSM	6853-09
	CHK. BY	DATE 7/20/94

REFERENCES:
ROY F. WESTON STUDIES CONDUCTED FOR USAEC

ASSUMPTIONS

- SLUDGE VOLUME = 10,000 YD^3
- BATCH OPERATION
- 80 DAYS COMPOSTING PER BATCH
- 15 DAYS MOB/DEMOB PER BATCH
- 4 TEMPORARY STRUCTURES
- 2 WINDROWS/STRUCTURE/BATCH
- 20% SLUDGE LOADING
- 500 YD^3/WINDROW ⇒ 100 YD^3 CONTAM SOIL/WINDROW

TREATED SOIL PER BATCH:

$$4 \text{ STRUCTURES} \times 2 \frac{\text{WINDROWS}}{\text{STRUCTURE}} \times \frac{100\ YD^3}{\text{WINDROW}} = 800\ YD^3$$

$$\Rightarrow \frac{800\ YD^3}{\text{BATCH}}$$

NUMBER OF BATCHES:

$$\frac{10{,}000\ YD^3 \text{ SLUDGE}}{800\ YD^3/\text{BATCH}} = 12.5 \text{ BATCHES}$$

OPERATING TIME:

$$12.5 \text{ BATCHES} \times 95 \frac{\text{DAYS}}{\text{BATCH}} = 1{,}187 \text{ DAYS}$$

⇒ ~ 1,200 DAYS OF OPERATION

⇒ ASSUME 3.5 YRS OF OPERATION

AMENDMENT:

$$400 \frac{YD^3}{\text{WINDROW}} \times 8 \frac{\text{WINDROWS}}{\text{BATCH}} \times 12.5 \text{ BATCHES} = 40{,}000\ YD^3$$

DENSITY OF AMENDMENT = 950 lb/YD^3

$$\Rightarrow \frac{40{,}000\ YD^3 \times 950\ lb/YD^3}{2000\ lbs/TON} = 19{,}000 \text{ TONS}$$

PROJECT	COMP. BY	JOB NO.
PROPELLANT BURNING GROUND OFF-SITE ANALYSIS COSTS (CONTAM SOIL DELINEATION)	JSM	6853-09
	CHK. BY	DATE 7/27/94

SURFACE SOIL

PRIMARY CONTAMINANTS	ANALYSIS COST
24DNT	$225
CPAH	407
AS	38
CU, ZN }	45
HG	49
SE	38
PB	30
	$832 => ~ $850

SUBSURFACE SOIL (LANDFILL 1 & 1949 PIT)

PRIMARY CONTAMINANTS	ANALYSIS COST
CPAH	$407
AS	38
CR, ZN }	45
PB	30
SE	38
	$558 => ~ $600

WASTE PITS	ANALYSIS COST
24DNT, 26DNT }	$225
CPAH	407
C6H6, TRCLE }	211
PB	30
	$873 => ~ $900

APPENDIX D.4

VENDOR INFORMATION: SOIL ALTERNATIVES

PROPELLANT BURNING GROUND

GEO•CON® INC.
GEOTECHNICAL CONTRACTING

April 29, 1993

Mr. John McKinnon
ABB ENVIRONMENTAL
110 Free Street
Box 7050
Portland, Maine 04112

Re: Shallow Soil Mixing

Dear Mr. McKinnon:

In response to your recent inquiry regarding Geo-Con's system for remediating and stabilizing lead contaminated soils to a depth of 18 inches, I have outlined the following approach and generalized cost estimate.

Geo-Con would propose to use a modified version of a CAT SF 250 road stabilizer machine to apply a pre-determined mixture of water and cement additives to the soil. The SF 250 is similar to a large farm tiller that has a series of harrows suspended from a carriage. The harrows have hollow stems that apply the metered cement-water mixture in precise amounts. The cement and water is pumped in from two mobile trucks that follow the SF 250 along and keep pace with the application.

The SF 250 system is capable of stabilizing soils to a depth of 10-12 inches in depth. What Geo-Con would propose is to stabilize the first ten inches of soil first. Then to follow behind with a motor grader and push the stabilized material into windrows. The motor grader's blade will be set to only excavate the first eight inches of stabilized material to allow for an overlap to ensure complete coverage.

The SF 250 would then follow behind and stabilize the underlying layer of soils. Once the bottom ten inches of soils are stabilized the motor grader would push back the first layer of stabilized soils and regrade the site.

Geo-Con would set up a portable batch plant on-site to provide storage and support to the stabilization activities. It is anticipated that geo-Con would be able to stabilize up to one thousand cubic yards of soil per day and would have a total contract length of approximately 90 days.

The cost for stabilizing approximately fifty thousand cubic yards of lead contaminated soils would be in the range of $45.00-$65.00 per cubic yard of soil. This per cubic yard price would exclude the cost of a treatability study and miscellaneous job site cost.

1000 White Horse Road • Voorhees, New Jersey 08043 • Tel (609) 772-1188 • FAX (609) 772-2009

Pittsburgh (Headquarters) (412)856-7700
California Office (510)887-2002
Chicago Office (708)335-4040
Florida Office (813)647-5888
Texas Office (817)383-1400

GEO·CON® INC.

Mr. John McKinnon
April 29, 1993
Page 2

If you should require any additional information, please do not hesitate to telephone my office at 609-772-1188. I look forward to speaking with you again sometime soon.

Sincerely,

GEO-CON, INC.

ROB LAROSE
District Manager

RL/efm

MKT\MCORR\ABB1

WESTON
MANAGERS DESIGNERS/CONSULTANTS
1 WESTON WAY
WEST CHESTER, PA 19380-1449
PHONE: 215-692-3030
FAX: 215-430-3124

29 March 1993

ABB Environmental Services
110 Free Street
P.O. Box 7050
Portland, ME 04112

Attention: Mr. John MacKinnon

Subject: Badger Army Ammunition Plant - Incineration

Dear John:

In response to your letter regarding the feasibility of incinerating soil contaminated with dinitrotoluene (DNT), Roy F. Weston, Inc. (WESTON•) is very experienced and is completing a similar incineration project for the U.S. Army Corps of Engineers. As part of a multiphase contract WESTON• is incinerating trinitrotoluene (TNT) contaminated soil at the Savanna Army Depot Activity (SADA) and Alabama Army Ammunition Plant (AAAP).

Upon reviewing your letter we would confirm the remediation goal of non detect (ND) less than 1 ppm is typical during operation of the rotary kiln incinerator on TNT or DNT. Based upon your data from Badger, we recommend that a pre-blending operation be included. Safety considerations require the maximum concentration of TNT in soil fed to the incinerator be below 10,000 ppm.

The site requirements for the incinerator generally should be in non-contaminated zone, or near level grade, above the 100 year flood plain and if possible capable of bearing loads in excess of 3,000 psf (this requirement can be overcome with pilings at additional costs).

The incinerator that WESTON would propose for both treatment cases listed is our TIS-20 (the TIS-20 is the same unit currently operating at SADA). A description of the process equipment, utility and site needs is provided in the attached brochure. During normal operation the TIS process discharge streams consist of treated kiln ash (bottom ash), fly ash (baghouse dust collector solids) and decon water. If hazardous metals are present in the soil, the fly ash may need stabilization prior to disposal.

For budgetary cost estimate, mobilization and demobilization will be approximately $3.0 Million Dollars and treatment costs will be $200 per ton from stockpile prepared to stockpile of treated ash assuming the soil contains no greater than 20% moisture. These costs do not include trial burn costs which will depend upon regulatory requirements or the cost of excavation, screening and blending since this will depend upon site layouts and distances.

If you need further information, please call me at (215) 430-7423.

Very truly yours,

ROY F. WESTON, INC.

Michael G. Cosmos, P.E.
Project Director
Treatment Systems

MGC:ma

Attachments

FLY ASH ≈ 10% OF SOIL VOLUME
(PER M. COSMOS, 4/27/93)

CARBTROL®
CORPORATION

39 Riverside Avenue
Westport, Connecticut 06880
1-800-242-1150 • (203) 226-5642
FAX (203) 226-5322

July 18, 1994

Mr. John McKinnon
ABB ENVIRONMENTAL SERVICES
110 Free Street
Portland, ME 04112

Dear Mr. McKinnon:

I am pleased to forward information on our CARBTROL equipment for the treatment of contaminated soils, you requested. These units are well suited for a six-month lease to treat your waste pit applications.

Enclosed is information describing our CARBTROL Soil Vapor Extractor (SVX). This pre-engineered Soil Vapor Extraction package is specifically designed to control the relative humidity in the gases for efficient utilization of the activated carbon. For this purpose, a moisture trap is provided to remove free moisture from the gas.

The SVX System consists of a vacuum exhauster, a moisture trap, manual flow control, air bleed valves, gauges and motor. The equipment is factory piped, wired and mounted on a steel skid. The air stream relative humidity is reduced below 50% by the moisture trap and by the heat of compression of the vacuum exhauster, thus increasing the efficiency of downstream carbon adsorption. Activated carbon adsorbers with either 200 or 2,000 lbs. of activated carbon can be supplied with the system to adsorb the volatile organics. CARBTROL offers a "Take-Back" service for spent non-hazardous carbon from UST sites.

Enclosed is the following descriptive information:

- Description of the SVX System and the G-4 Adsorbers
- Illustration of the System
- Lease Agreement and Quotation

We look forward to discussing your specific application further with you once you have had an opportunity to review the enclosed information.

Sincerely,

James W. Davidson

James W. Davidson
JWD:vlm
Enclosures

CARBTROL®
CORPORATION

July 18, 1994

Mr. John McKinnon
ABB ENVIRONMENTAL SVCS.

QUOTATION

ITEM	QTY	DESCRIPTION	UNIT PRICE	EXT. PRICE
1	1	Lease - SVX-105T Soil Vapor Extractor for six (6) months.	$1,634.00	$1,634.00
		Unit may be purchased at anytime during the lease. The price is $9,800.00. Monthly fees paid before purchase will apply to sale at 85% of payments received.		
2	2	Lease - Model G-4 Adsorbers with 1,000 lbs. of Vapor Phase Carbon. Initial payment includes first month rent and reactivation of non-hazardous classified carbon.	$1,995.00	$3,990.00
3	2	Each additional month per G-4	$295.00	$590.00
4	1	CARBTROL will arrange for reactivation of hazardous waste classified spent carbon at the end of the lease.	$200.00	$200.00
		Waste Characterization Analysis		
		• Volatile Organic Scan	$525.00	$525.00
		• Semi-Volatile Organic Scan:	$900.00	$900.00

SALESPERSON: JWD
TERMS: Net 30 Days
COMMENTS: F.O.B. Bridgeport, CT

QUOTATION VALID FOR SIXTY DAYS

JWD:vlm

TERMS & CONDITIONS

1. PROPOSAL. CARBTROL®'s purpose to furnish the Customer the equipment as covered by this proposal and specifications at the prices stated herein.

Prices are firm for shipment within six (6) months of the order date if the order is placed within 60 days.

For shipments made more than six (6) months from the date of the order, pricing will be that in effect at time of shipment. (If shipment is delayed for reasons under control of the Company, then the price shall remain firm).

All the information in the proposal is confidential and has been prepared for Customer use solely in considering the purchase of the equipment described. Transmission of all or any part of this information to others by Customer for other purposes is unauthorized without CARBTROL®'s written consent.

2. TERMS OF PAYMENT. Net payment within 30 days from invoice date subject to credit approval by CARBTROL®. CARBTROL® reserves the right to invoice on finished goods if customer holds delivery beyond projected shipping date. CARBTROL® reserves the right to invoice on partial shipments. All overdue amounts of the purchase price shall bear interest at the rate of 1 1/2% per month.

3. SHIPMENT. F.O. B. plant as per CARBTROL®'s proposal suitable for domestic shipment, unless otherwise specified. Shipping dates given therein are approximate only and are computed from time of receipt at CARBTROL® Office of all details pertaining to the order essential to its proper execution.

4. WARRANTY. All equipment manufactured by CARBTROL® is warranted to be free from defects in material and workmanship for a period of 18 months from the date of shipment or 12 months from the date of start up, whichever comes first. CARBTROL® will repair or replace any part or parts during the warranty period free of charge. F.O. B. factory provided our examinations shows the equipment to be truly defective when used for the purpose intended. The obligation of CARBTROL® is limited solely to repair not to exceed the cost of the defective equipment considered on a unit basis, or replacement of said equipment. This obligation shall be conditioned upon prompt written notice being given to CARBTROL®. CARBTROL® MAKES NO WARRANTY AS TO FITNESS OF ITS PRODUCTS FOR SPECIFIC APPLICATIONS BY THE BUYER OR AS TO PERIOD OF SERVICE UNLESS CARBTROL® SPECIFICALLY AGREES OTHERWISE IN WRITING AFTER THE PROPOSED USAGE HAS BEEN MADE KNOWN. The foregoing warranty is exclusive and in lieu of all other warranties expressed or implied, including but not limited to any warranty of merchantability or of fitness for a particular purpose. Commodities not manufactured by CARBTROL® are warranted or guaranteed to the extent and in the manner they may be warranted or guaranteed to CARBTROL® by the manufacturer thereof, and to the extent such warranty or guaranty may reasonably be enforced without litigation by CARBTROL®.

5. LIMITATION OF LIABILITY. In no event as a result of breach of contract, warranty or negligence shall CARBTROL® be liable for special or consequential damages including but not limited to loss of profits or revenues, loss of any equipment, cost of capital, cost of substitute equipment, facilities or services, downtime costs or claims of purchasers of the Customer for such damages. Further, CARBTROL® will not be liable for any delay in the performance of contracts and orders, or in the shipment and delivery of goods, or for any damage suffered by the liable for any delay in the performance of contracts and orders, or in the shipment and delivery of goods, or for any damage suffered by the Customer by reason of delay, when such delay is, directly or indirectly, caused by or in any manner arises from fires, floods, accidents, riots, war, Government interference, priorities, embargoes, strikes, shortage of labor, fuel, materials or supplies, inadequate transportation facilities or any other cause or causes whether or not similar in nature to any of those hereinbefore specified beyond CARBTROL®'s control.

6. SERVICE. Where service in the nature of installation, demonstration or repair of any equipment beyond that specifically included in the quoted price, CARBTROL® will render such services at its normal charges plus overtime and living and traveling expenses for a mechanic and/or engineer.

7. PERFORMANCE. When performance of CARBTROL®'s equipment is based on data furnished by Customer, it should be understood that CARBTROL®'s performance figures are estimated only, based on the reliable engineering practice. The actual performance obtained by Customer may be influenced by any changes in conditions prevailing in Customers plant or site.

8. PATENTS. CARBTROL® assumes no responsibility for any claims that said equipment infringes on rights or patents of others.

9. CLAIMS. Claims for loss or damage in transit are the responsibility of the consignee; however, CARBTROL® will lend assistance. Any claims for shortages not covered by the common carrier, in order to receive consideration, must be made within ten (10) days from date of delivery.

10. CANCELLATION. Any orders placed for equipment and commodities as offered in this proposal shall not be subject to cancellation except with CARBTROL®'s consent, and then only upon the following conditions:

Standard Equipment - (Defined as catalogued equipment ordinarily carried in stock.) When cancellation is accepted, CARBTROL® reserves the right to make a cancellation charge up to 25% of the purchase price.

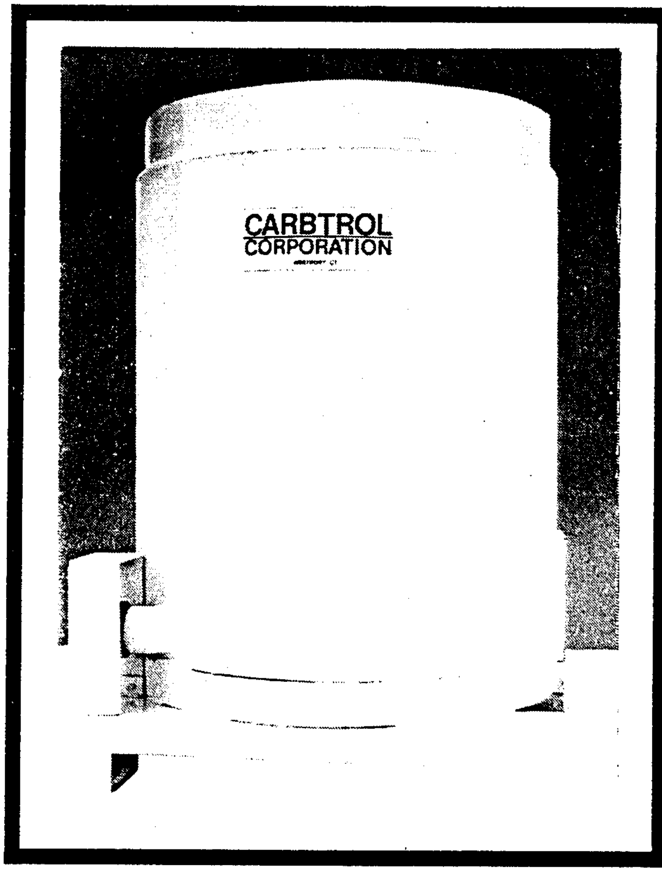
Special Equipment - (Defined as equipment manufactured for special requirements and not stocked as standard product.) Cancellation will be accepted upon payment of a percentage of the total special equipment price equal to the percentage of the total work completed.

11. TAXES. Our proposal does not include Federal, State or Local Sales, Privilege, Use or other taxes of any kind applicable to the sale of the equipment involved. These taxes shall be paid by the Customer or, in lieu thereof, the Customer shall provide CARBTROL® with a tax exemption certificate acceptable to the proper taxing authority.

12. OTHER. This agreement shall be construed in accordance with the laws of the State of Connecticut. These Terms and Conditions are the only terms and conditions that will be binding upon the parties unless additional terms are set forth in writing and agreed to between the parties in writing.

CARBTROL®

AIR PURIFICATION ADSORBERS
1,000 LB. ACTIVATED CARBON G-4
1,800 LB. ACTIVATED CARBON G-6



FEATURES

- Low pressure drop.
- High activity carbon.
- Fork lift fittings for easy handling.
- 4" Ø slotted inlet distributor.
- DOT rated. Acceptable for transport of hazardous waste.

SPECIFICATIONS

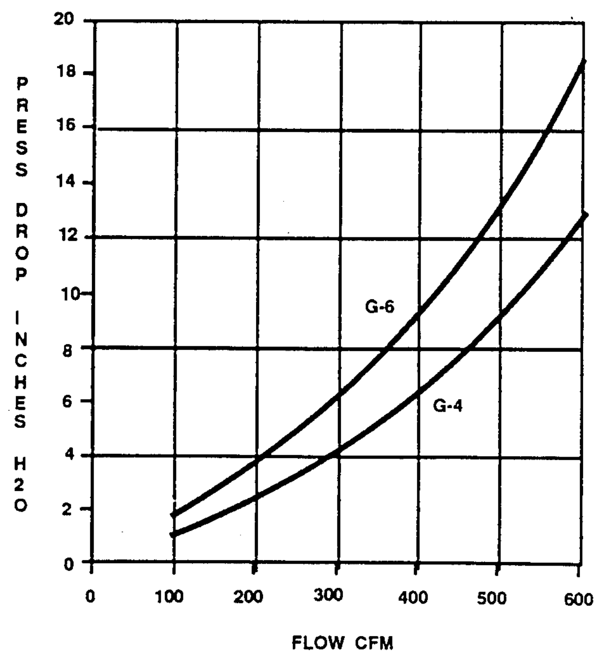
G-4

CARBON:	1,000 lbs.
DIMENSIONS:	45-1/2" Ø x 62" height
SHIPPING WT:	1,500 lbs.

G-6

CARBON:	1,800 lbs. *
DIMENSIONS:	45-1/2" Ø x 86" overall ht.
SHIPPING WT:	2,500 lbs.

* 2,000 lbs. option available



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CORPORATION

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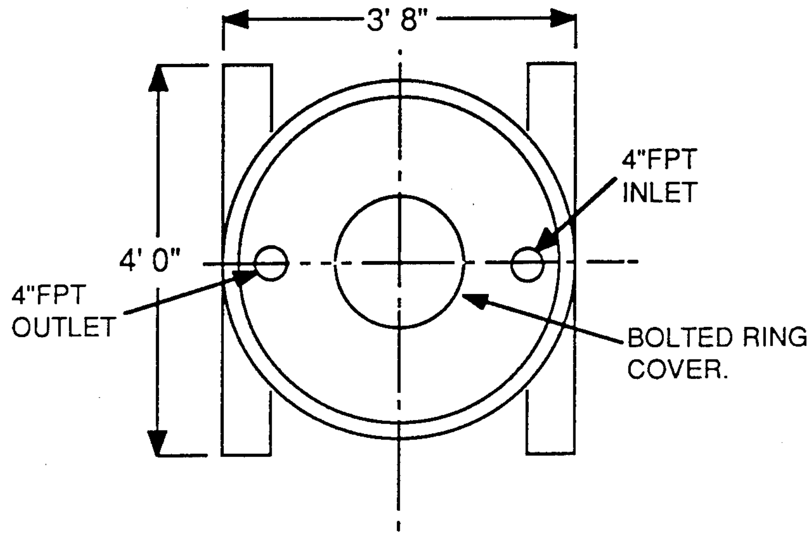
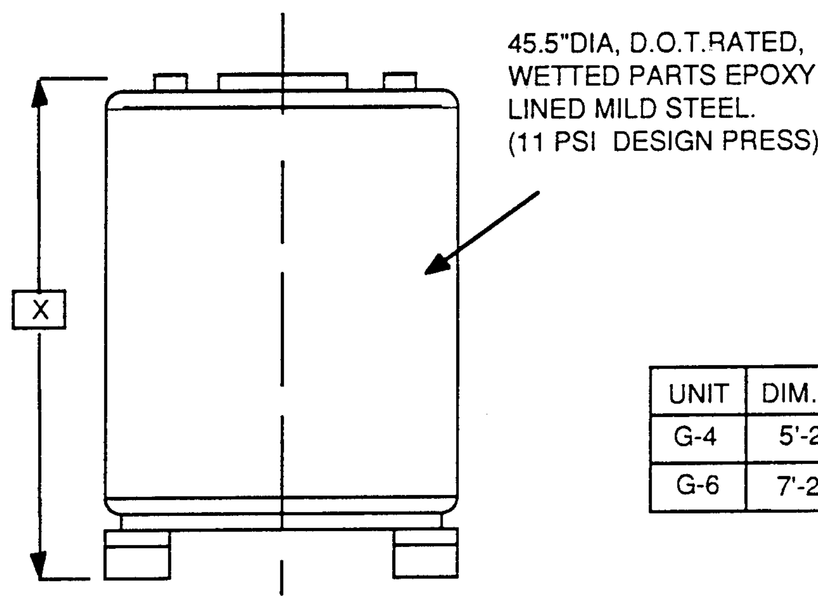
 AT-411/#1

CARBTROL®

AIR PURIFICATION ADSORBERS

1,000 LB. ACTIVATED CARBON G-4
1,800 LB. ACTIVATED CARBON G-6





UNIT	DIM. "X"
G-4	5'-2"
G-6	7'-2"

CARBTROL®
CORPORATION

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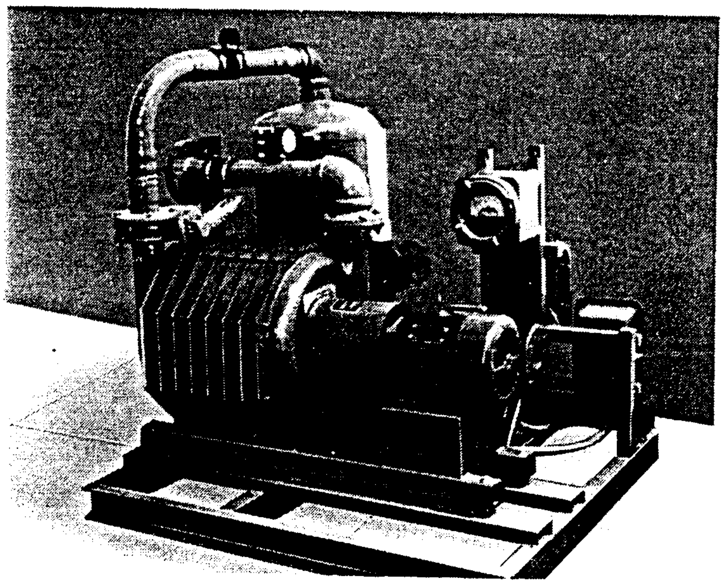
CARBTROL®

SOIL VAPOR EXTRACTOR - (SVX-T)



SIZES

Two standard sizes:

105 CFM at 6" Hg Vacuum
250 CFM at 7.8" Hg Vacuum

Other sizes custom designed

COMPONENTS

- Vacuum exhauster, turbine type, spark resistant.
- Moisture trap.
- Air dilution valve.
- Sample port.
- Vacuum, temperature and pressure gauges.
- Explosion proof motor and controls.
- Factory piped, wired and mounted on a steel skid.

FEATURES

- Constant vacuum over 80-99% of flow range.
- Relative humidity reduction for improved carbon efficiency.
- Removal of free moisture.
- Low noise level - 85 decibels.
- No vibration - no foundation required.
- Easy handling, fork lift fittings.
- Supplied complete, ready to operate.

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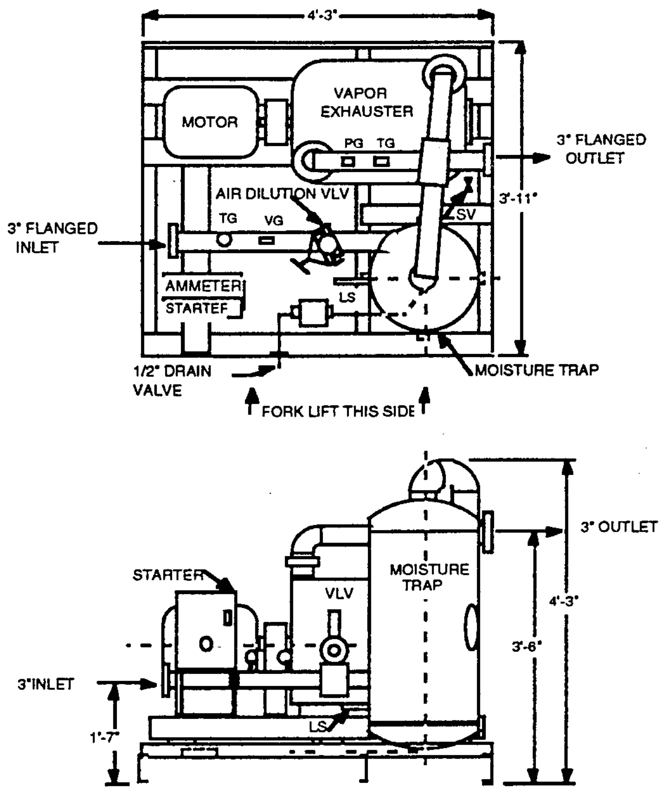
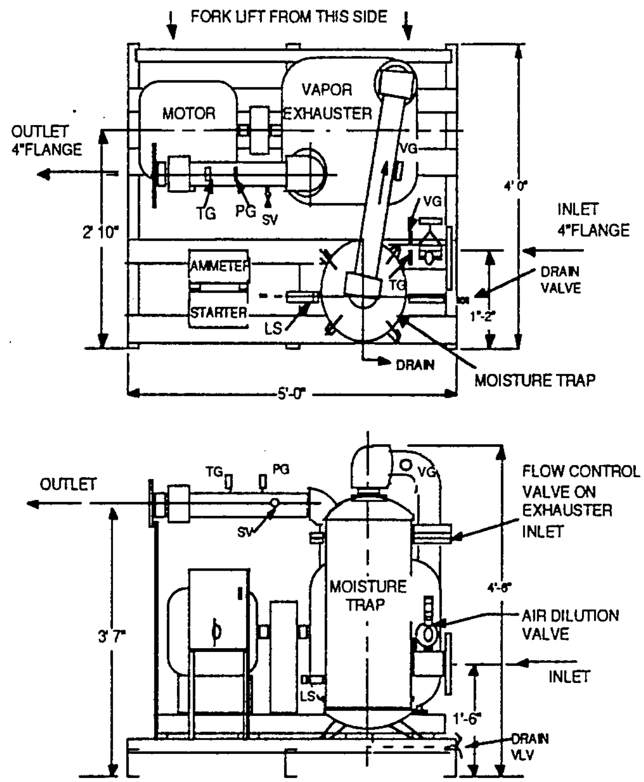
 AT-500/501/#1

CARBTROL®

SOIL VAPOR EXTRACTOR - (SVX-T)

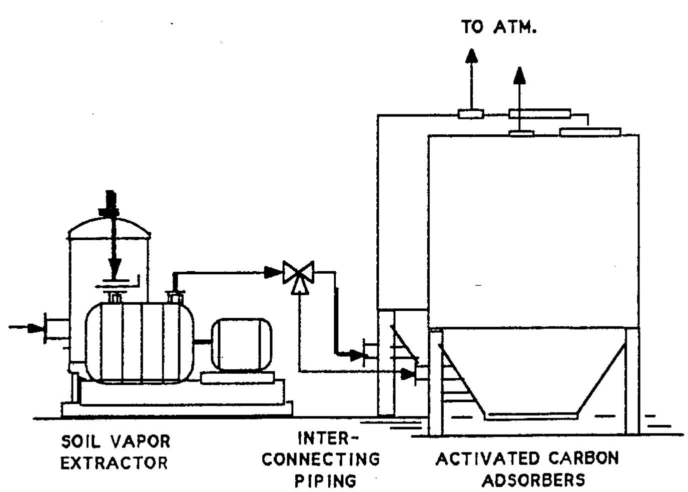


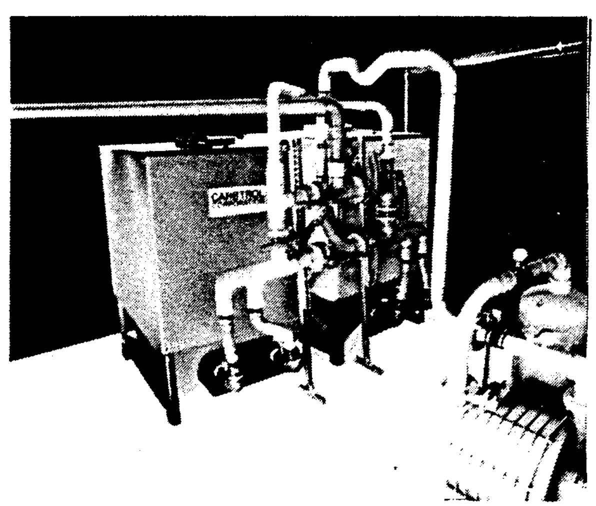
105 CFM at 6" Hg



250 CFM at 7.8" Hg

LEGEND
LS- Level Switch
PG-Press Gauge
TG-Temp Gauge
VG- Vacuum Gauge
SV- Sample Valve





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GEO·CON® INC.

GEOTECHNICAL CONTRACTING

April 15, 1994

Mr. John MacKinnon
ABB ENVIRONMENTAL SERVICES
110 Free Street
Portland, ME 04112

**Re: Badger Army Ammunition Plant
Slurry Wall Containment**

Dear John,

Thank you for the opportunity to assist you in your development of a remedial approach at the above referenced project site. I have received the information that you had faxed to my office dated April 11, 1994 and have reviewed the narrative and soil borings.

It is my understanding that ABB is proposing to form an in-situ tank in the ground and to use this tank as a containment vessel for soil flushing. As part of this approach, it would be necessary to construct a slurry wall roughly 110 ft in diameter, extending 110 ft below grade and required permeability for the wall would be 10^{-7}.

It has been noted that there is no confining layer for the wall to key into and provide an impermeable barrier across the bottom of the "tank". The remedial solution would require the installation of a non-natural bottom confining layer for which the wall to key into and to provide a bottom to the tank.

Solution:

Geo-Con can install a bottom to the tank by the use of high powered jet-grouting technology. Essentially, this would involve the drilling of multiple overlapping shafts within the confines of the tank area. The jet grout technology would inject a cement grout mixture into the native soils at a depth of approximately 105 feet from grade and extend down to 110 feet from grade.

This method of injecting overlapping columns of grout mixture into the soil would eventually provide a contiguous bottom to the tank area and the approximate location of the bottom of the containment, so as to provide a material for which the wall to key into to.

1000 White Horse Road • Voorhees, New Jersey 08043 • Tel (609) 772-1188 • FAX (609) 772-2009

Pittsburgh (Headquarters) (412)856-7700
California Office (510)887-2002

Florida Office (813)647-5888
Texas Office (817)383-1400

GEO•CON INC.

The wall would be installed using Geo-Con's Deep Soil Mixing technology. This would entail the mixing of soils in place where the wall would be located and injecting into the soil sodium bentonite to provide a impermeable barrier.

I have enclosed information on both systems with this letter as well as some technical briefs of past projects. Outlined below is a conceptual estimate of project costs. I have made some basic assumptions and they as listed as well.

Assumptions:

- Prevailing Labor Rates Will Apply.
- Full Health And Safety Protocol
- Perimeter Air Monitoring To Be Done By Others
- Project Duration Is One Year.

Conceptual Pricing:

Mobilization..................................	$ 522,000.00	X 1
Containment Wall Construction..................	$ 530,000.00	} X 3 PITS
Jet Grouting...................................	$1,498,374.00	
Total..	$~~2,551,794.00~~ 6,607,122.00	JBM ABB-ES

If you should have any questions regarding the technology or you would like to schedule a meeting sometime down the road, please do not hesitate to call.

Sincerely,

GEO-CON, INC.

ROB LAROSE
District Manager

RL/efm

MCORR\R413ABB.LTR

NICHOLSON CONSTRUCTION COMPANY
P.O. BOX 98
BRIDGEVILLE, PA 15017
(412) 221-4500
FAX (412) 221-3127

May 4, 1994

Mr. John McKinnon
ABB Environmental
110 Free Street
Portland, ME 04112

RE: Army Ammunition Plant
Baraboo, WI
NCC Prelim # 93186

Dear John:

The purpose of this letter is to follow up on our recent discussions about the Baraboo project. I have attached:

-experience sheets from SMW Seiko, our joint-venture partners, re: environmental and ground water cutoffs,

-experience sheets from our sister company and joint venture partner regarding jet grouting technology, and

-a copy of the jet grouting chapter from the soon to be published text by Xanthakos, Bruce, and Abramson.

The jet grouting experience sheets do not reflect the current three ongoing jet grouting projects that we are performing with Rodio in San Francisco, New York, and Boston. I can provide you some details on these projects as they near completion. Incidentally, Nicholson provided the anchors to Kajima for the project that was done by Seiko for BFI.

Upon review of your preliminary scheme for grouting a cone intended to intercept the circular cutoff walls, I offer the following clarifications:

-budget price for non-grouted drill hole lengths (e.g. 110' typical) is \$25/L.F.

-budget price for grouted length, drilling and grouting included, (e.g. 80' typical) is \$70/L.F.

That part is the good news. The bad news is that there is no assurance that one row of jet grouting will create an impermeable cone when drilling to the depths indicated. It is likely, however, that a positive cutoff can be attained at these depths with three concentric cones. Two of the cones, to be drilled first would be centered radially at about 5'. With 3 foot nominal grout columns, this would leave a 2' nominal space between the concentric cones. The third pass, or final concentric cone would then be drilled and grouted to fill this remaining space.

I took the liberty of quickly repeating your cost calculation, without verifying the formula for the surface of the cones and get about $2.9 million/pit which is $8.7 million for all three pits, using a triple pass approach.

Another piece of good news is that the budgeted quantity of circular cutoff is reduced with this scheme, from depths of around 120′ to 80′.

As a followup to this, I will attempt to find out what is the best achievable drilling tolerance in this ground for the jet grouting operation in order to verify the validity and level of conservatism in the triple cone assumption. That is, once I research the implications of tighter tolerances then a pattern of a single cone or double concentric cones can be explored.

In addition, please be aware that the costs of inefficiencies associated with working in haz-mat conditions are not included in these budget costs. Surcharges of 25-50% can result from these inefficiencies. As we noted before, it is probably most economical to be sure that the dimensions of the vertical cutoffs and under grouting, are sized to be sure that all the work is placed through clean material. From this, depending upon the regulatory requirements for this site, costs for PPE and 40 hour training needs to be added, but inefficiencies due to shutdowns and evaluation of unsuspected materials may be able to be avoided, therefore resulting in minimal production unknowns, as compared to creating a vertical plug.

I appreciate being able to work with you on this most interesting project and hope to speak with you again soon. Also, right now is an ideal opportunity for you and any interested colleagues to visit us at the I-90 Logan Airport site. We currently are performing both jet grouting and SMW operations through at least late May. Please call me if you would like to schedule a visit.

Sincerely,
NICHOLSON CONSTRUCTION COMPANY

Seth L. Pearlman, P.E.
Regional Marketing Manager

SLP:drd

Enclosures

cc: PJN
DEH
DDU
DAB
G. Dugnani
JR Takeshima

NICHOLSON

NICHOLSON CONSTRUCTION COMPANY
P.O. BOX 98
BRIDGEVILLE, PA 15017
(412) 221-4500
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May 5, 1994

Mr. John McKinnon
ABB Environmental
110 Free Street
Portland, ME 04112

RE: Army Ammunition Plant
Baraboo, WI
NCC Prelim #93186

Dear John:

This letter is to inform you of a correction in our letter to you dated May 4, 1994, that you should be receiving May 6, 1994. There was a typographical error in the calculations, therefore the price on page 2 of the letter should read, $2.9 million/pit, which is $8.7 million for all three pits.

I have attached a revised copy of the May 4 letter. Please replace the first one sent to you. I apologize for the inconvenience.

Sincerely,

NICHOLSON CONSTRUCTION COMPANY

Seth L. Pearlman, P.E.
Regional Marketing Manager

SLP:drd

Enclosures

cc: PJN
DEH
DDU
DAB
G. Dugnani
JR Takeshima

Millgard
ENVIRONMENTAL
Corporation

May 17, 1994

Mr. John MacKinnon
ABB Environmental Services
PO Box 7050
261 Commercial St.
Portland, ME 04112

Re: In-Situ remediation of DNT contaminated soils at the Badger Army Ammunition Plant, Baraboo, Wisconsin

Dear John:

Millgard Environmental Corporation (MEC) is pleased to have the opportunity to provide you with the following budget pricing scenarios for in-situ solidification/stabilization and barrier isolation of DNT contaminated soils at the aforementioned site.

The MecTool Remediation Delivery System® would be utilized to perform remedial construction. Initially, MEC proposes a pilot scale demonstration to evaluate the selected MEC method eg. complete treatment of entire soil volume in each waste pit or "containment barrier" wall/floor approach. Our suggested method would be comprised of in-situ placement of an impermeable barrier from a depth of 85.0 to 100.0 feet below ground surface (b.g.s.) in addition to a perimeter cutoff wall. The barrier floor would provide aquifer protection by essentially impeding the vertical migration of DNT, Trichloroethylene, and Benzene. The barrier floor reagent would consist of a cement/flyash grout containing approximately 1.0 - 5.0 % activated carbon. The perimeter cut-off wall would consist of cement/flyash, bentonite, or combination of several reagents to obtain at least 1×10^{-6} cm/sec permeability and effectively inhibit lateral soil gas migration.

Based on our calculations, which include an adjustment for 20% overlap of treatment columns, the total volume of soil to be treated in the three waste pits is approximately 105,000 cubic yards (CY). For the barrier floor/wall option, the volume of soil to be treated in the 85.0 - 100.0 bgs range in the three pits is estimated to be approximately 16,000 CY and the cut-off walls would contain approximately 23,000 CY. Based on an average full scale production rate of approximately 5 units per day, we estimate treatment of the entire contents to be completed within 50 weeks following mobilization and equipment setup. The "containment barrier" option would require approximately 30 - 35 weeks for completion based on production of 5 wall units per day and 8 floor units per day. An additional 7 - 10 days is required for engineered layout of treatment area and equipment calibration prior to treatment, and equipment decontamination and teardown post treatment.

An estimated price for a full scale pilot demonstration including mobilization/demobilization, labor and materials is presented in Table 1. Tables 2 and 3 present budget pricing for the "containment barrier" floor/wall and entire content treatment, respectively. An estimate of the cost of materials is included in this budget proposal, based on previous treatability studies for remediation by solidification/stabilization of similar contaminated soils. A more detailed soil analysis, and

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treatability study, would be essential to fine-tune the chemistry necessary for desired optimal results and pricing. A preliminary treatability study estimate price is included in the following quotation.

The following tables present pricing based on site information received to date from ABB Environmental Services, Portland, Maine and is subject to change as further information is received:

TABLE 1
Pilot Study Budget Pricing Based on 1994 Start

Item	Qty.	Unit Price	Total
Treatability Study	1 each	$ 45,000	$ 45,000
Mobilization/Equip. Setup/Labor/Decon/ Demobilization	1 each	$ 80,000*	$ 80,000
Labor - Production Period *5 Man Crew*	10 days	$ 3,000	$ 30,000
Equipment- Manitowoc 3900W & Air Handling Equipment	1 rig 10 days	$ 3,000	$ 30,000
Materials (cement/flyash, carbon, fuel, etc.)	10 days	$ 5,000	$ 50,000
Total Budget Pricing			**$ 235,000**

*Assumes a full mobilization/demobilization to/from Livonia, Michigan

The following work **is** included in the pilot study budget pricing:

1) Perform a series of treatment columns to the design depth of treatment or as deemed adequate by owner/engineer. Test areas would encompass approximately 50 ft^2 in each waste pit, not to exceed 100 ft^2. Reagent to be batched off-site and delivered.

2) Engineering layout with controls established by others. Daily production reports, including all information particular to our operations and relating to job progress.

3) One mobilization/demobilization of all MEC equipment and labor.

TABLE 2 "Containment Barrier" Floor/Wall of DNT Contaminated Soil Badger Army Ammunition Plant			
Item	**Qty.**	**Unit Price**	**Total**
Mobilization/Equip. Setup/Labor/Decon/ Demobilization	1 each	$ 80,000	$ 80,000
Labor - Production Period *7 Man Crew*	190 days	$ 4500.00/day	$ 855,000
Equipment-Manitowoc 3900W & Air Handling Equipment	1 rig 190 days	$ 3500.00/day	$ 665,000
Batch Plant Operations On-Site	190 days	$ 1000.00/day	$ 190,000
Materials (cement/flyash, carbon, fuel, etc.)	190 days	$ 6500.00/day	$ 1,235,000
Total Budget Pricing ————————		————————	**$3,025,000**

The following work **is** included in the "containment barrier" wall/floor budget pricing:

1) In-Situ solidification/stabilization of barrier wall (approximately 345 LF X 6.0 feet in diameter to a depth of 100.0 feet bgs) and floor (approximately 340 - 6.0 foot diameter columns X 15.0 feet deep/waste pit) of DNT, Benzene, and TCE contaminated soils. This includes: injecting a 25% volume : volume cement/flyash grout containing approximately 5% activated carbon (floor of waste pit #1 only) into the soil while mixing to produce an impermeable barrier.

2) Engineering layout with controls established by others. Daily production reports, including all information particular to our operations and relating to job progress.

3) One mobilization/demobilization of all MEC equipment and labor.

To: John MacKinnon, ABB Environmental Services

Fr: Bill Herceg, MEC

Re: Questions from 22 April, 1994 memo

* In-situ containment and solidification/stabilization both have applicability to this site given the soil type and contaminant concentrations. DNT, at the concentrations present in waste pit 1, however, will require the addition of activated carbon at a weight to weight of soil ratio of 5 - 10%. This will significantly impact the cost of completely solidifying the entire soil column. Also, there appears to be a very dense silty sand layer from 13.0 - 26.0 feet bgs in waste pit 1 where a majority of the high concentration DNT is tied up. Depending on available pore space in this zone, injection of solidification reagent could be limited.

* A much more economical approach would involve the placement of a perimeter cut-off wall around the waste pit in addition to the placement of a barrier floor from a depth of 85.0 - 100.0 feet below ground surface. In waste pits 2 and 3, there does not appear to be a need for a carbon based grout given the results presented in Figures 6-31, 3-15, and 3-14.

* Our proposed approach(es) both consist of drilling vertically into and through contaminated material that exists above uncontaminated material. The MecTool™ Remediation Delivery System is designed to vertically mix soil over the complete diameter of the treatment column. Vertical migration would be limited to residual contamination on the mixing blade itself being "dragged" downward, however, the effective depth of the blade cut is approximately 1.0 inch/rpm with a vertical lift of 9.0 inches based on the slight upward angle of the mixing blade. Also, it is possible to have subsequent downward migration of contaminants aided by infiltration through the mixed zone and upward migration of soil gas vapors prior to placement of a surface confining layer.

* MEC would employ the use of a surface foaming agent or grout layer to provide a seal to prevent emmissions during construction. A containment shroud could also be utilized to capture fugitive emmisions at the surface of the treatment column with subsequent air treatment. The explosive concern would be minimized to the extent possible utilizing non-sparking equipment and compatible drilling techniques.

* For complete treatment eg. solidification/stabilization of the entire contents of each waste pit, we estimate the project to be completed in approximately 40 - 50 weeks after mobilization. The estimated time to complete the barrier floor/wall method is approximately 30 weeks following mobilization.

* Refer to the budget pricing letter, 17 May, 1994

* Our system does not require any on-site utilities, however, an available on-site water source would enhance the efficiency of batch plant operations, if conducted on-site. For equipment setup, decon, office and equipment trailer support zone, and decontamination, we require an area approximately 200 feet x 50 feet to erect the production rig and between 25,000 and 100,000 ft^2 for support zone.

* Refer to the budget pricing letter, 17 May, 1994.

MILLGARD ENVIRONMENTAL CORPORATION
MEMORANDUM

July 18, 1994

To: John MacKinnon, ABB Environmental Services

Fr: Bill Herceg, MEC

Re: MEC's proposed installation procedure for the barrier wall/floor containment "cells" - Waste Pits 1 - 3.

As per our discussion during our meeting at your office on July 7, 1994, we would like to clarify the following Phase I installation procedures:

To assure a hydraulically competent containment "cell", the wall and floor of the containment "cell" will be constructed concurrently. The perimeter wall and floor construction would consist of surface layout using a computer aided positioning system (CAPSY) to generate precise center to center of column points. The diameter of the perimeter wall will be consistent with the design diameter of the waste pit. The CAPSY system will be utilized during the entire reagent injection process for both the wall and floor elements. The injection process for the wall will commence at ground surface and terminate at 100.0 feet bgs and withdrawal will be performed with reagent injection from 100.0 feet bgs to ground surface. The injection process for the floor will commence at a depth of 85.0 feet bgs to a depth of 100.0 feet bgs and terminate at a depth of 85.0 feet bgs during withdrawal. Perimeter columns will be positioned to provide a minimum overlap of 20% and to assure a minimum wall thickness of 36.0 inches.

Vertical position control is afforded by the rigidity of the kelly bar, the plumbness of the fixed points (drill attachment, cabling, etc.), and high torque to overcome normal debris and obstructions. The CAPSY system will also be utilized to control the vertical plumbness during MecTool™ penetration and withdrawal. The operator receives real time information from CAPSY regarding a deflection from vertical, therefore adjustments can be made in subsequent columns, thus assuring complete coverage of the floor element and lateral fusion of the wall and floor elements. The reagent mix design would consist of 70 - 90% Portland I cement, 8.5 - 28.5% flyash, and 1.5% activated carbon. Based on the diameter of the mixing blade selected for this site, a minimum of 20% overlap is necessary to assure complete coverage of the floor element of the containment "cell".

Phase II is the MEC/IGT proposed approach involves IGT's Chemical Biological Treatment (CBT) process on the contained soils. MEC equipment and labor would be utilized to inject and mix the CBT process for IGT during this phase of construction.

cc: Bob Kelley, IGT
Bill Newman, MEC

CAPSY POSITIONING SYSTEM

Computer Aided Positioning System

A. Application at Badger Army Ammunition Plant, Baraboo, WI site -
the CAPSY system utilizes reflective targets, randomly mounted on the periphery of the treatment area, to read it's position and that of the treatment column centers. The system can also be programmed to provide real time control of vertical plumbness during advancement and withdrawal of MecTool. Prior to initiation of treatment operations, the system must be programmed to interpret these reflectors. This is accomplished by setting up two known points on the site (primary and secondary reference points), which will be utilized to determine the azimuth angle for the layout grid. It is only necessary to set up the CAPSY system one time for the entire treatment process.

Step 1 - enter the primary and secondary reference point X-Y coordinates

Step 2 - place CAPSY on the primary reference point and the setup reflector on the secondary reference point, enter

Step 3 - move the setup reflector to a randomly placed intermediate reference point, to complete a triangular pattern, enter

Step 4 - place CAPSY on the secondary reference point, enter

Step 5 - place the setup reflector on the primary reference point, enter

Step 6 - place CAPSY on the intermediate reference point, enter

B. Placement of CAPSY on Manitowoc 3900W crane - the CAPSY system is mounted on the drill attachment scaffold to allow unobstructed scanning of the reflective targets.

C. Placement of Reflective Targets on the site - Targets are permanently mounted at a height conducive to scanning by the CAPSY system laser on the periphery of the treatment area. For a treatment area of the size of the three waste pits at the Badger site, it is anticipated that 20 - 30 reflectors would be positioned on the site.

D. Post Treatment Position Memory - The CAPSY system has the additional feature of electronically recording and identifying each soil column upon completion of the mixing cycles. This feature assures treatment of all column locations within the grid, and thereby eliminates the possibility of by-passing any column within the system as with conventional layout procedures.

FAX COVER SHEET
IGT
HEADQUARTERS

INSTITUTE OF GAS TECHNOLOGY
3424 SOUTH STATE STREET
CHICAGO, IL 60616-3896 USA

Phone no.: (312) 949-3650
Fax no.: (312) 949-3700

To:	John S. MacKinnon
	207 775-5401 work
	207-772-4762 fax
From:	Bob Kelley, (312) 949-3809
Date/Time:	July 22, 1994; 12:44
Subject:	Additional information on Phase II of the Millgard/IGT treatment alternative for the Badger Ammunition Site

I am sending a copy of the information that you requested.

- Detailed description of actual site treatment
  -- treatability study
  -- sampling/monitoring protocols
- Specfic information on the degradability of TNTs and DNTs

I will call you on Monday to get your comments and to determine if you need anything else from me.

Thank-You

cc/
Bill Newman, Millgard
vjs

Phase II: Millgard/ IGT treatment process: Chemical/Biological Destruction of Waste Materials

Description

After the containment structure has been put in place in Phase I, the same equipment will be used to distribute the chemical and biological reagents. The exact protocol for applying the chemical and biological reagents will be determine during the treatability studies. However, if a conservation approach is taken, several pass of the MecTool will be necessary for both the biological and chemical treatment to deliver the necessary reagents. Also, if the contaminate levels are above the treatments goals after one cycle of chemical and biological treatment then it may be necessary to do a any cycle of treatment.

The key components of this treatment alternative are:

- Treatability Testing
- Site Preparation for Chemical Treatment
- Site Preparation for Biological Treatment
- Monitoring and Confirmatory Sampling

Treatability Testing

The objectives of this study are to obtain design-specific and performance-specific treatability data for the remediation of the site. The performance-specific objectives are (1) preliminary estimates of long-term cleanup goals for the site and the time required to achieve those goals and (2) an economic estimate for design, installation, and operation of the enhanced bioremediation process (CBT).

In the initial laboratory treatability studies, we propose to conduct first Phase I of the studies with the DNT-contaminated soil from the site. Phase I consists of 5 technical components (Figure 1): soil characterization, soil/DNT desorption tests, bioactivity tests, liquid-phase DNTs biodegradation, and soil-water slurry-phase biodegradation . At the end of this phase of the study, a progress meeting will be convened, and it will be decided if we should proceed to Phase II. Phase II is a series of bench-scale experiments that will provide necessary engineering and economic information for the design of a field-scale study.

Site Preparation for Chemical Treatment

The chemical treatment may be applied in two steps because the Fenton's reagent is not stable and must be mixed in the presents of the contaminated material. First, a ferric sulfate solution will be mixed into the soil. Second, hydrogen peroxide will be mixed into the soil. The reaction will proceed until all the hydrogen peroxide has decomposed. The treatability studies will help to determine the concentration of the reagents and the time needed for the treatment.

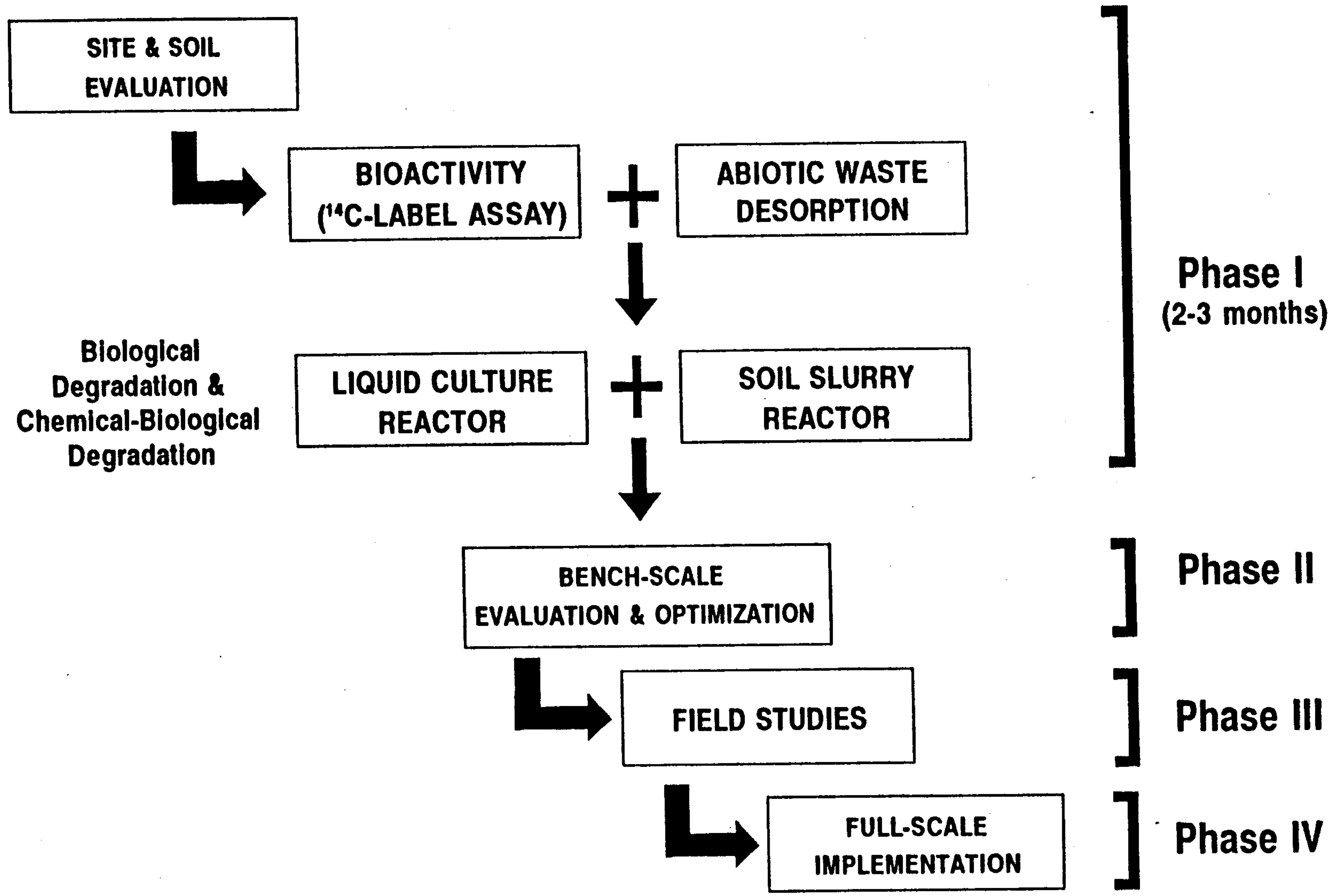

Figure 1. IGT/GRI TREATABILITY PROTOCOL FOR EFFECTIVE REMEDIATION OF MGP SOILS

Site Preparation for Biological Treatment

Once the chemical treatment has been completed, the biological treatment will be initiated. Because the Fenton's reagent creates an acidic environment, the first step will be to rise the pH to 6-7. If needed nutrients, water and additional oxygen sources can be added. Also, if needed endogenous, DNT-degrading microbes can be added to the soil. Again, the treatability studies will help to determine the concentration of the reagents and the time needed for the treatment.

Monitoring and Confirmatory Sampling

The progress of the chemical and biological treatment will be monitored by split spoon sampling in the treatment cell. Surface (0-6 ft.), subsurface (10-30 ft.), and deep (>50 ft.) Samples will be taken after the chemical treatment and during the biological treatment. A colorimetric assay will be used to detect the parent compounds, DNTs. As significant removal is detected then HPLC/MS methods will be used to monitor the products of possible oxidative intermediates. Once the treatment goals has possibly been meet. Statistically valid, composite samples will be collected and analyzed by GC/MS and HPLC/MS for parent and intermediate compounds.

Degradation of Nitroaromatics

Both the biological and chemical degradation of nitroaromatics, such as TNTs and DNTs, has been well studied during the past decade. Biological degradation has been studied under both aerobic[2-4,11,20,33,35-38,40,41] and anaerobic[1,32,34] conditions. Chemical degradation has been evaluated with wet-air-oxidation (WAO), Supercritical water oxidation (SCWO),[22] UV/ H_2O_2,[12-14] O_3/H_2O_2[6,18], and Fenton's reagent[27]. Several field demonstration ulitizing both chemical and biological technologies have been preformed.[8,19,43,42] Therefore, there is a great resource of literature and reports from which we can draw to predict the success of the IGT's Chemical/ Biological treatment (CBT) process on the materials at the Badger Ammunition Site.

TNTs and DNTs appear to readily degraded biologically degraded in both aerobic and anaerobic conditions. In general, DNTs appear to degrade more quickly and more completely than TNTs. An aerobic bacterial consortium was shown to degrade 2,4,6- trinitrotoluene(TNT). At an initial concentration of 100 ppm, 100% of the TNT was transformed to intermediates within 108 h. Removal of the parent TNT from the soil cultures by the strictly anaerobic microflora have been shown to occurred within 4 days.

A significant amount of work has been done with the white-rot fungus.[11,37,40] White rot fungi such as *Phanerochaete chrysosporium* degrade the nonrepeating, nonstereoselective, insoluble polymer lignin under conditions of nutrient limitation. The attack on lignin principally involves extracellular peroxidases (ligninases) and hydrogen peroxide. Hydroxyl radicals may also make a significant contribution.[11] This mechanism is similar to the action of Fenton's reagent. The *P. chrysosporium* system has been found effective on many diverse substrates, including TNT. However, field demonstration have been unpredictable.

DNTs are degraded by a unique pathway that results in the removal of both aromatic nitrogroup before ring cleavage. The *Pseudomonas* sp. grew on DNT at concentrations approaching its solubility in water (187 mg/l), and the activity of the induced cells were not inhibited when an excess of DNT crystals was present in the medium.[36] The degradative pathway used by this organism is well known. In fact, Suen et al have conducted studies of DNT degradation on the molecular level and have shown the involvement of three distinct plasmids.[38] Degradative intermediates and their toxicities are known as well as the kinetics for various organisms. Boopathy et al. found that sulfate-reducing (anaerobic) bacterium, *Desulfovibrio* sp. (B strain), was able to use various nitroaromatic compounds, such as 2,4-dinitrophenol, 2,4-dinitrotoluene and 2,6-dinitrotoluene, as sole N-sources for growth.[1] These nitroaromatics also served as catabolic electron acceptors in the absence of sulfate in the culture medium. Over 60% of the nitroaromatics were transformed within 6 days of incubation.

Generally, studies have shown a decrease in toxicity with degradative intermediates of TNTs and DNTs from biological reactions, as measured by mutagenicity with *Salmonella typhimurium*.[8,39] However, TNTs biodegradation involves some toxic intermediates. The first intermediates observed were 4-amino-2,6- dinitrotoluene and its isomer 2-amino-4,6- dinitrotoluene. The rate of degradation of these intermediates was very slow, reflecting possible difficulties in metabolizing the intermediates of TNT to CO_2.

Williams et al. reported on two field-scale demonstrations that were conducted to study composting as a means of treating explosive- and propellant-contaminated sediments.[42,43] After 22 wk, total explosives were reduced by 99% (from 17,872 to 74 ppm) in the thermophilic pile. The second field demonstration was conducted at the Badger Army Ammunition Plant. Test sediments contained nitrocellulose, which was reduced from 13,086 to 16 ppm after 101 days in a thermophilic pile. Other field tests were performed to examine the kinetics of 2,4-dinitrotoluene degradation by *Pseudomonas* sp. PR7 in a fluidized bed reactor.[44]

Chemical degradation of TNTs and DNTs has also been well studied. Li et al. evaluated the treatment of dinitrotoluene (DNT) process wastewaters by supercritical water oxidation. (SCWO).[22] Under SCWO conditions, destruction efficiencies >99% were achieved. Fenton's reagent has proven to be an inexpensive and powerful oxidant which has been shown to oxidize a wide variety of organics. Mohanty et al. have shown that 2,4 DNT can be effectively oxidized in aqueous solutions with Fenton's reagent.[22] At a H_2O_2 :DNT : Fe2+ ratio of 20:1:2.5 (molar), 2,4-DNT was completely removed in 5 hours. UV/H_2O_2 has also been shown to be effective on 2,4-dinitrotoluene.[12-14] Degradation begins with hydroxylation of TNTs and DNTs to di- and trihydroxybenzenes, followed by benzene-ring cleavage to produce carboxylic acids and aldehydes. On further photooxidation, these carboxylic acids and aldehydes will eventually be converted to harmless CO_2, NO_3 salts and water.

In conclusions, degradation of DNTs in soils can occur by either biological or chemical means. Both biological and chemical degradation appear to proceed through less toxic intermediates. In water, chemical oxidation has been shown to increase biodegradability.[18] We have shown that the extent and rate of degradation of other aromatics, such as PAHs and PCBs, increase when chemical and biological degradative process are combined. Therefore, IGT's CBT process should have good results on DNT-contaminated wastes from the Badger Ammunition site.

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TABLE 4 Treatment of Entire Contents of Waste Pits 1 - 3 IGT CBT Process Badger Army Ammunition Plant			
Item	**Qty.**	**Unit Price**	**Total**
Mobilization/Equip. Setup/Labor/Decon/ Demobilization	1 each	$ 80,000	$ 80,000
Labor - Production Period *7 Man Crew*	852 Shifts	$ 4500/shift	$ 3,834,000
Equipment- Manitowoc 3900W & Air Handling Equipment	1 Rig 852 Shifts	$ 3500/shift	$ 2,982,000
Batch Plant Operations On-Site	852 Shifts	$ 1000/shift	$ 852,000
Materials (chemicals, nutrients, & fuel, etc.)	852 Shifts	$ 4930/shift	$ 4,200,360
Total Budget Pricing ————		————	**$ 11,948,360**

The following work **is** included in the above budget pricing:

1) In-Situ Chemical/Biological remediation of approximately 105,000 cubic yards of DNT, Benzene, and TCE contaminated soils. This includes: injecting the patented IGT treatment solution into the soil while mixing.

2) Engineering layout with controls established by others. Daily production reports, including all information particular to our operations and relating to job progress.

3) One mobilization/demobilization of all MEC equipment and labor.

February 23, 1993

NICHOLSON CONSTRUCTION COMPANY
P.O. BOX 98
BRIDGEVILLE, PA 15017
(412) 221-4500
FAX (412) 221-3127

Mr. John MacKinnon
ABB Enviromental
110 Free Street
Portland, Maine 04112

Re: "Badger" Army Ammunitions Plant Cleanup
Baraboo, Wisconsin
NCC Prelim # 93186

Dear John:

The pupose of this letter is to summarize budget pricing for two schemes that are part of your overall plan to perform cleanup of three burning pits at the site noted above. These two schemes are:

1) Construct three circular structural walls using the Hydromill, to place 3' thick structural reinforced concrete. Each ring is 110' in diameter and the continuous panels are placed to about 120' depth. The soil inside the rings is to be excavcated to a depth of about 100' and incinerated. The Hydromill can construct the ring structure to tolerances that minimize the eccentricity created and therefore, no additional internal bracing is assumed to be required.

2) Construct three circular non-structural cutoff walls with a plan diameter of about 110' to a depth of about 150' using the SMW (Soil-Mixed-Wall) technique, and proceed to clean up the contaminants using soil cleansing techniques.

It is my understanding that scheme 1 is very expensive relative to the excavation and incineration costs, as compared to the passive soil cleansing proposed with scheme 2.

I have assumed that the work from the surface to install either circular wall will be done in level "C" conditions at worst. In addition, any special insurance to be required beyond our normal contractor's umbrella policy is not considered.

The budget prices for these two items are:

SCHEME 1	125,000 SQ FT CONCRETE WALL USING HYDROMILL	
	$65 TO $70/SQ FT	$8.1 TO $8.75 MILL
SCHEME 2	156,000 SQ FT SMW WALL	
	$35 TO $40/SQ FT	$5.5 TO $6.25 MILL

I hope that this information is suitable for your purposes at this stage. As the project develops, we would be happy to discuss it with you further. As we also dicussed, a meeting at our current SMW site at the Logan Airport, or a meeting or your office could be set up at your convenience. Meanwhile, if you require any other information, or have any questions or comments, please do not hesitate to call.

Sincerely,
NICHOLSON CONSTRUCTION

Seth L. Pearlman, P.E.
Chief Design Engineer

Enclosures
SMW brochure, Hydromill Brochure, and General NCC Brochures

cc: PJN, DEH, DDU, J.R. Takeshima, DRD(files)

ALTERNATIVE REMEDIAL
TECHNOLOGIES, INC.

NEWS RELEASE

14497 North Dale Mabry Hwy., Suite 140, Tampa, FL 33618
Contact: Michael J. Mann, P.E., (813) 264-3571

For Immediate Release

SUPERFUND SUBCOMMITTEE CHAIRMAN TOURS KING OF PRUSSIA SITE

October 11, 1993 -- Sen. Frank R. Lautenberg (D-N.J.) recently toured the King of Prussia Technical Corporation Superfund (KOP) Site in Winslow, New Jersey, and got a firsthand look at a soil washing process being operated by Alternative Remedial Technologies, Inc. (ART) that could help speed the cleanup of hazardous waste sites in New Jersey and nationwide. Senator Lautenberg is chairman of the Senate Superfund subcommittee which oversees the program.

After touring the site the Senator noted "Such innovative cleanup technology holds the key to a cleaner future at an affordable price; the rest of the country should benefit from New Jersey's experience. In just six months, this facility will turn 20,000 tons of soils and sludges contaminated with heavy metals into soil good enough to be redeposited into its original location. It'll do so far more quickly and cheaply than traditional cleanup methods." He also remarked that "New Jersey is way ahead of the curve in this area. The soil washing facility represents the cutting edge of technology. It's one of the largest facilities of its kind operating in the country today."

ART is a 50% joint venture between Geraghty & Miller, Inc., a leading U.S. environmental services firm, and Heidemij Realisatie, a major Dutch engineering and environmental firm located in Arnhem, The Netherlands. ART is the prime contractor for soil washing and groundwater remediation at the KOP site. ART is performing the soil washing operations and has subcontracted Geraghty & Miller to do the groundwater remediation portion of the project. The full-scale soil washing operation began in late June 1993, after a successful pilot run was completed. Soil washing operations are expected to conclude by mid-October 1993 and groundwater cleanup equipment will be installed after the soil washing plant is removed. Contaminants at the site are primarily heavy metals which leached into the soil and groundwater following an industrial waste recycling operation at the site in the early-1970's.

ART provides soil washing services throughout the United States and is headquartered in Tampa, Florida. For additional information, contact Michael J. Mann, P.E., Alternative Remedial Technologies, Inc., 14497 North Dale Mabry Highway, Suite 140, Tampa, FL 33618. Phone (813) 264-3571.

APPENDIX D.5

COSTS: GROUNDWATER ALTERNATIVES

PROPELLANT BURNING GROUND

DATE: 03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION GW-1 MINIMAL ACTION
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION GW-1 MINIMAL ACTION
COST SUMMARY TABLE

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
DIRECT COST OF OPTION GW-1 MINIMAL ACTION				
INSTITUTIONAL CONTROLS				$10,000
TOTAL DIRECT COST OF OPTION GW-1 MINIMAL ACTION				$10,000
INDIRECT COST OF OPTION GW-1 MINIMAL ACTION				
HEALTH AND SAFETY			0.00%	$0
LEGAL, ADMIN, PERMITTING			0.00%	0
ENGINEERING			0.00%	0
SERVICES DURING CONSTRUCTION			0.00%	0
TOTAL INDIRECT COST OF OPTION GW-1 MINIMAL ACTION				$0
TOTAL CAPITAL (DIRECT + INDIRECT) COST				$10,000
OPERATING AND MAINTENANCE COSTS				
TOTAL COST REPLACEMENT WELLS				$22,000
TOTAL PRESENT WORTH OF REPLACEMENT WELLS IN YEAR 16, 32, 48 @ 5%				$17,000
TOTAL ANNUAL OPERATING AND MAINTENANCE COSTS				$387,000
TOTAL PRESENT WORTH OF ANNUAL O&M COSTS (5% FOR SIXTY-FIVE YEARS)				$7,415,000
TOTAL PRESENT WORTH OF OPERATING AND MAINTENANCE COSTS				$7,432,000
TOTAL COST OF OPTION GW-1 MINIMAL ACTION				$7,442,000

DATE: 03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION GW-1 MINIMAL ACTION
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION GW-1 MINIMAL ACTION

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
INSTITUTIONAL CONTROLS	1	LS	10000.00	$10,000
OPERATING & MAINTENANCE COSTS (WELLS REPLACED IN YEARS 16, 32, 48)				
REPLACEMENT WELLS	2	EA	10000.00	$20,000
CONTINGENCY ~10%				2,000
TOTAL COST REPLACEMENT WELLS				$22,000
ANNUAL OPERATING & MAINTENANCE COSTS				
GROUNDWATER SAMPLING & ANNALYSIS	1	LS	345000.00	$345,000
EDUCATIONAL PROGRAMS	1	LS	5000.00	5,000
FIVE YEAR SITE REVIEW @ $10,000 EVERY FIVE YEARS	1	LS	1809.75	1,810
CONTINGENCY ~10%				35,190
TOTAL ANNUAL OPERATING & MAINTENANCE COSTS				$387,000

DATE: 03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION GW-2 IRM AND CARBON ADSORPTION
JOB # 6853-09

LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT

ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION GW-2 IRM AND CARBON ADSORPTION
COST SUMMARY TABLE

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
DIRECT COST OF OPTION GW-2 IRM AND CARBON ADSORPTION				
SITE PREPARATION AND MOB/DEMOB				$402,000
EXTRACTION SYSTEM CONSTRUCTION				2,855,000
CARBON ADSORPTION TREATMENT FACILITY CONSTRUCTION				579,000
PROCESS EQUIPMENT				1,177,000
EFFLUENT PIPE MODIFICATION				12,000
IRM FACILITY MODIFICATION				28,000
TOTAL DIRECT COST OF OPTION GW-2 IRM AND CARBON ADSORPTION				$5,053,000
INDIRECT COST OF OPTION GW-2 IRM AND CARBON ADSORPTION				
HEALTH AND SAFETY			5.00%	$253,000
LEGAL, ADMIN, PERMITTING			5.00%	253,000
ENGINEERING			10.00%	505,000
SERVICES DURING CONSTRUCTION			10.00%	505,000
TOTAL INDIRECT COST OF OPTION GW-2 IRM AND CARBON ADSORPTION				$1,516,000
TOTAL CAPITAL (DIRECT + INDIRECT) COST				$6,569,000
OPERATING AND MAINTENANCE COSTS				
TOTAL COST REPLACEMENT WELLS				$22,000
TOTAL PRESENT WORTH OF REPLACEMENT WELLS IN YEARS 16, 32, 48 @ 5%				$17,000
TOTAL ANNUAL OPERATING AND MAINTENANCE COSTS				$1,485,000
TOTAL PRESENT WORTH OF O&M COSTS (5% FOR SIXTY-FIVE YEARS)				$28,454,000
TOTAL COST OF OPTION GW-2 IRM AND CARBON ADSORPTION				$35,040,000

DATE:03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION GW-2 IRM AND CARBON ADSORPTION
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION GW-2 IRM AND CARBON ADSORPTION SITE PREPARATION AND MOB/DEMOB DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
EQUIPMENT (IN OR OUT)				
FRONT END LOADER	2	EA	520.00	$1,040
DUMP TRUCKS	4	EA	260.00	1,040
BACKHOE	2	EA	520.00	1,040
OFFICE TRAILER	6	MON	155.00	930
STORAGE TRAILER (2 EA)	12	MON	155.00	1,860
TRAILER SET-UP & DELIVERY, REMOVAL	3	EA	310.00	930
TOILET (2 EA*6 MON/EA*4.2 WK/MON)	50	WK	25.00	1,250
WATER CLR (2EA*6MON/EA*4.2WK/MON)	50	WK	25.00	1,250
WATER (50 WK * 5 DAY/WK)	250	DAY	15.00	3,750
TELEPHONE SERVICE	6	MON	520.00	3,120
ELECTRICAL HOOK-UP	1	LS	2500.00	2,500
ELECTRICAL POWER	6	MON	300.00	1,800
PICK-UP (2 EA * 6 MON/EA)	12	MON	1035.00	12,420
OFFICE EQUIPMENT	6	MON	1035.00	6,210
PUMPS, TOOLS MINOR EQUIPMENT	1	LS	5000.00	5,000
CLEAR AND GRUB STUMPS - MEDIUM TREES	0.5	AC	6375.00	3,188
STAGING & PARKING				
12" GRAVEL	2420	SY	6.50	15,730
COVERED STAGING AREA	2400	SF	35.00	84,000
LABORER (2 MEN*10 DAY/MAN*8 HR/DAY)	160	MNHR	30.50	4,880
CARPENTER (2 MEN*10 DAY/MAN*8 HR/DAY)	160	MNHR	39.00	6,240
ELECTRICIAN (2 MEN*10 DAY/MAN*8 HR/DAY	160	MNHR	42.50	6,800
SITE SUPERINTENDANT (6 MON*210 HR/MON)	1260	MNHR	62.25	78,435
FOREMAN (6 MON * 210 HR/MON)	1260	MNHR	51.75	65,205
CLERK/TYPIST (6 MON * 168 HR/MON)	1008	MNHR	26.00	26,208
UNDEVELOPED DESIGN DETAILS ~20%				67,175
TOTAL SITE PREPARATION AND MOB/DEMOB				$402,000

DATE: 03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION GW-2 IRM AND CARBON ADSORPTION
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION GW-2 IRM AND CARBON ADSORPTION EXTRACTION SYSTEM CONSTRUCTION DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
EXTRACTION WELLS	6	EA	36000.00	$216,000
EXTRACTION WELL PUMPS	2	EA	50000.00	100,000
	4	EA	25000.00	100,000
BURIED 6" DIA PVC FORCE MAIN	5500	LF	25.00	137,500
BURIED 10" DIA PVC FORCE MAIN	5000	LF	45.00	225,000
CONDUITS - 2 X 2, 4" DIA RGS	5500	LF	100.00	550,000
- 2 X 4, 3" DIA RGS	5000	LF	150.00	750,000
POWER WIRING - 4C-500 MCM	5500	LF	30.00	165,000
4C-300 MCM	5000	LF	20.00	100,000
INSTRUMENTATION WIRING	31000	LF	1.15	35,650
UNDEVELOPED DESIGN DETAILS ~20%				475,850
TOTAL EXTRACTION SYSTEM CONSTRUCTION				$2,855,000

DATE: 03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION GW-2 IRM AND CARBON ADSORPTION
JOB # 6853-09

LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT

ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION GW-2 IRM AND CARBON ADSORPTION
CARBON ADSORPTION TREATMENT FACILITY CONSTRUCTION

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
PRE-ENGINEERED STRUCTURE ON CONCRETE PAD	3200	SF	55.00	$176,000
ARCHITECTURAL ITEMS	3200	SF	11.00	35,200
PLUMBING	3200	SF	4.00	12,800
HVAC	3200	SF	6.00	19,200
ELECTRICAL/INSTRUMENTATION WIRING	3200	SF	22.00	70,400
FIRE PROTECTION	3200	SF	5.50	17,600
FURNISHINGS	3200	SF	2.25	7,200
PARKING AREA	2500	SY	15.00	37,500
ELECTRICAL SERVICE				
TAP ELECTRICAL TRANSMISSION LINE	1	LS	10000.00	10,000
UTILITY POLES, 60' HIGH	2	EA	1250.00	2,500
500 KVA TRANSFORMER	1	LS	15500.00	15,500
SWITCHGEAR	1	LS	70000.00	70,000
OVERHEAD CABLE	200	LF	10.00	2,000
BURIED 3/4" DIA WATER LINE	75	LF	20.00	1,500
BURIED 6" DIA INFLUENT LINE	75	LF	25.00	1,875
BURIED 10" DIA EFFLUENT LINE	75	LF	45.00	3,375
UNDEVELOPED DESIGN DETAILS ~20%				96,350
TOTAL CARBON ADSORPTION TREATMENT FACILITY CONSTRUCTION				$579,000

DATE:03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION GW-2 IRM AND CARBON ADSORPTION
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION GW-2 IRM AND CARBON ADSORPTION PROCESS EQUIPMENT DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
FILTER ASSEMBLY	1	LS	20000.00	$20,000
INFLUENT EQUALIZATION TANK, 5000 GAL	1	EA	8500.00	8,500
INFLUENT TRANS PUMP, 1500 GPM, 30 HP	1	EA	10000.00	10,000
INFLUENT TRANS PUMP, 2000 GPM, 65 HP	1	EA	15000.00	15,000
CARBON ADSORPTION UNIT, 2 - 20000 LB	2	EA	300000.00	600,000
INITIAL CARBON CHARGE	4	EA	15500.00	62,000
EFFLUENT TANK, 5000 GAL	1	EA	8500.00	8,500
EFFLUENT PUMP, 1500 GPM, 165 HP	1	EA	27000.00	27,000
EFFLUENT PUMP, 2000 GPM, 220 HP	1	EA	30000.00	30,000
PIPING, FITTINGS, VALVES BETWEEN COMPONENTS				
10" DIA PVC	350	LF	130.00	45,500
8" DIA PVC	150	LF	75.00	11,250
INSTRUMENTATION				
FLOW TRANSMITTER - 10" DIA	3	EA	10000.00	30,000
PRESSURE TRANSMITTER	9	EA	1500.00	13,500
LEVEL SWITCH	6	EA	2500.00	15,000
PROGRAMMABLE LOGIC CONTROLLER	1	LS	25000.00	25,000
PANEL MTD INDICATORS	3	EA	1000.00	3,000
PANEL MTD RECORDER, 3 PEN	1	EA	5000.00	5,000
ANNUNCIATOR	1	LS	10000.00	10,000
CONTROL PANEL	1	LS	35000.00	35,000
AIR COMPRESSOR	1	LS	6500.00	6,500
UNDEVELOPED DESIGN DETAILS ~20%				196,250
TOTAL PRECESS EQUIPMENT				$1,177,000

DATE: 03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION GW-2 IRM AND CARBON ADSORPTION
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION GW-2 IRM AND CARBON ADSORPTION EFFLUENT PIPE & IRM FACILITY MODIFICATION DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
EFFLUENT PIPE MODIFICATIONS				
SPLICE IN 8-FT SECTIONS OF 10" DIA PIP AT MANHOLE	3	EA	2000.00	$6,000
INSTALL AIR/VACUUM RELIEF VALVE				
IN EXISTING MANHOLE	1	EA	750.00	750
IN NEW MANHOLE	1	EA	3250.00	3,250
UNDEVELOPED DESIGN DETAILS ~20%				2,000
TOTAL EFFLUENT PIPE MODIFICATION				$12,000
IRM FACILITY MODIFICATIONS				
INFLUENT TRANSFER PUMP, 500 GPM, 25 HP	1	EA	6500.00	$6,500
EFFLUENT TRANSFER PUMP, 500 GPM, 55 HP	1	EA	11500.00	11,500
MOTOR STARTER, SIZE 2 - RE-USE EXISTING				
MOTOR STARTER, SIZE 4 REPLACES SIZE 3	1	EA	4000.00	4,000
INFLUENT TRANSFER PUMP POWER CIRCUIT - RE-USE EXISTING				
EFFLUENT TRANSFER PUMP POWER CIRCUIT 4#2 & 1.5" RGS	100	LF	15.00	1,500
UNDEVELOPED DESIGN DETAILS ~20%				4,500
TOTAL IRM FACILITY MODIFICATIONS				$28,000
OPERATING & MAINTENANCE COSTS (WELLS REPLACED IN YEARS 16, 32, 48)				
REPLACEMENT WELLS	2	EA	10000.00	$20,000
CONTINGENCY ~10%				2,000
TOTAL COST REPLACEMENT WELLS				$22,000

DATE:03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION GW-2 IRM AND CARBON ADSORPTION
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION GW-2 IRM AND CARBON ADSORPTION
ANNUAL O&M COSTS

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
CARBON ADSORPTION TREATMENT FACILITY OPERATION				
PUMPING ELECTRICAL LOAD - 235 KW	2058600	KWHR	0.04	$82,344
CARBON REPLACEMENT	12	TIMES	15500.00	186,000
LABOR - 20 HR/WK	1040	MNHR	40.00	41,600
BUILDING LIGHT & POWER - 19.2 KW	168192	KWHR	0.04	6,728
SAMPLING (3 SAMPLES/BIWEEKLY)				
EPA MTD 624 VOAs	78	EA	275.00	21,450
EPA MTD 625 SVOAs	78	EA	518.00	40,404
INORGANICS	78	EA	163.00	12,714
IRM FACILITY OPERATION				
PUMPING ELECTRICAL LOAD - 85 KW	744600	KWHR	0.04	29,784
CARBON REPLACEMENT	6	TIMES	15500.00	93,000
LABOR - 20 HR/WK	1040	MNHR	40.00	41,600
BUILDING LIGHT & POWER - 11 KW	96360	KWHR	0.04	3,854
SAMPLING (4 SAMPLES BIWEEKLY)				
EPA MTD 624 VOAs	104	EA	275.00	28,600
EPA MTD 625 SVOAs	104	EA	518.00	53,872
INORGANICS	104	EA	163.00	16,952
TREATED GROUNDWATER DISCHARGE SAMPLING (1 SAMPLE TWICE PER MONTH)				
EPA MTD 624 VOAs	24	EA	275.00	6,600
EPA MTD 625 SVOAs	24	EA	518.00	12,432
INORGANICS	24	EA	163.00	3,912
GROUNDWATER MONITORING	1	LS	345000.00	345,000
MAINTENANCE COSTS @ 5% OF TOTAL CONSTRUCTION COST	5.00%		4210833.33	210,542
UNDEVELOPED DESIGN DETAILS ~20%				247,612
TOTAL ANNUAL O&M COSTS				$1,485,000

DATE: 03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION GW-4 IRM AND AIR STRIPPING/CARBON ADSORPTION
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION GW-4 IRM AND AIR STRIPPING/CARBON ADSORPTION
COST SUMMARY TABLE

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
DIRECT COST OF OPTION GW-4 IRM AND AIR STRIPPING/CARBON ADSORPTION				
SITE PREPARATION AND MOB/DEMOB				$402,000
EXTRACTION SYSTEM CONSTRUCTION				2,855,000
AIR STRIPPING/CARBON ADSORPTION TREATMENT FACILITY CONSTRUCTION				749,000
PROCESS EQUIPMENT				1,571,000
EFFLUENT PIPE MODIFICATION				12,000
IRM FACILITY MODIFICATION				28,000
TOTAL DIRECT COST OF OPTION GW-4 IRM AND AIR STRIPPING/CARBON ADSORPTION				$5,617,000
INDIRECT COST OF OPTION GW-4 IRM AND AIR STRIPPING/CARBON ADSORPTION				
HEALTH AND SAFETY			5.00%	$281,000
LEGAL, ADMIN, PERMITTING			5.00%	281,000
ENGINEERING			10.00%	562,000
SERVICES DURING CONSTRUCTION			10.00%	562,000
TOTAL INDIRECT COST OF OPTION GW-4 IRM AND AIR STRIPPING/CARBON ADSORPTION				$1,686,000
TOTAL CAPITAL (DIRECT + INDIRECT) COST				$7,303,000
OPERATING AND MAINTENANCE COSTS				
TOTAL COST REPLACEMENT WELLS				$22,000
TOTAL PRESENT WORTH OF REPLACEMENT WELLS IN YEARS 16, 32, 48 @ 5%				$17,000
TOTAL ANNUAL OPERATING AND MAINTENANCE COSTS				$1,474,000
TOTAL PRESENT WORTH OF O&M COSTS (5% FOR SIXTY-FIVE YEARS)				$28,243,000
TOTAL COST OF OPTION GW-4 IRM AND AIR STRIPPING/CARBON ADSORPTION				$35,563,000

DATE:03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION GW-4 IRM AND AIR STRIPPING/CARBON ADSORPTION
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION GW-4 IRM AND AIR STRIPPING/CARBON ADSORPTION
SITE PREPARATION AND MOB/DEMOB

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
EQUIPMENT (IN OR OUT)				
FRONT END LOADER	2	EA	520.00	$1,040
DUMP TRUCKS	4	EA	260.00	1,040
BACKHOE	2	EA	520.00	1,040
OFFICE TRAILER	6	MON	155.00	930
STORAGE TRAILER (2 EA)	12	MON	155.00	1,860
TRAILER SET-UP & DELIVERY, REMOVAL	3	EA	310.00	930
TOILET (2 EA*6 MON/EA*4.2 WK/MON)	50	WK	25.00	1,250
WATER CLR (2EA*6MON/EA*4.2WK/MON)	50	WK	25.00	1,250
WATER (50 WK * 5 DAY/WK)	250	DAY	15.00	3,750
TELEPHONE SERVICE	6	MON	520.00	3,120
ELECTRICAL HOOK-UP	1	LS	2500.00	2,500
ELECTRICAL POWER	6	MON	300.00	1,800
PICK-UP (2 EA * 6 MON/EA)	12	MON	1035.00	12,420
OFFICE EQUIPMENT	6	MON	1035.00	6,210
PUMPS, TOOLS MINOR EQUIPMENT	1	LS	5000.00	5,000
CLEAR AND GRUB STUMPS - MEDIUM TREES	0.5	AC	6375.00	3,188
STAGING & PARKING				
12" GRAVEL	2420	SY	6.50	15,730
COVERED STAGING AREA	2400	SF	35.00	84,000
LABORER (2 MEN*10 DAY/MAN*8 HR/DAY)	160	MNHR	30.50	4,880
CARPENTER (2 MEN*10 DAY/MAN*8 HR/DAY)	160	MNHR	39.00	6,240
ELECTRICIAN (2 MEN*10 DAY/MAN*8 HR/DAY	160	MNHR	42.50	6,800
SITE SUPERINTENDANT (6 MON*210 HR/MON)	1260	MNHR	62.25	78,435
FOREMAN (6 MON * 210 HR/MON)	1260	MNHR	51.75	65,205
CLERK/TYPIST (6 MON * 168 HR/MON)	1008	MNHR	26.00	26,208
UNDEVELOPED DESIGN DETAILS ~20%				67,175
TOTAL SITE PREPARATION AND MOB/DEMOB				$402,000

DATE: 03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION GW-4 IRM AND AIR STRIPPING/CARBON ADSORPTION
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION GW-4 IRM AND AIR STRIPPING/CARBON ADSORPTION

EXTRACTION SYSTEM CONSTRUCTION DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
EXTRACTION WELLS	6	EA	36000.00	$216,000
EXTRACTION WELL PUMPS	2	EA	50000.00	100,000
	4	EA	25000.00	100,000
BURIED 6" DIA PVC FORCE MAIN	5500	LF	25.00	137,500
BURIED 10" DIA PVC FORCE MAIN	5000	LF	45.00	225,000
CONDUITS - 2 X 2, 4" DIA RGS	5500	LF	100.00	550,000
- 2 X 4, 3" DIA RGS	5000	LF	150.00	750,000
POWER WIRING - 4C-500 MCM	5500	LF	30.00	165,000
4C-300 MCM	5000	LF	20.00	100,000
INSTRUMENTATION WIRING	31000	LF	1.15	35,650
UNDEVELOPED DESIGN DETAILS ~20%				475,850
TOTAL EXTRACTION SYSTEM CONSTRUCTION				$2,855,000

DATE:03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION GW-4 IRM AND AIR STRIPPING/CARBON ADSORPTION
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION GW-4 IRM AND AIR STRIPPING/CARBON ADSORPTION
AIR STRIP/CARBON ADSORP TREATMENT FACILITY CONSTRUCTION

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
PRE-ENGINEERED STRUCTURE ON CONCRETE PAD	5000	SF	50.00	$250,000
ARCHITECTURAL ITEMS	5000	SF	10.00	50,000
PLUMBING	5000	SF	3.50	17,500
HVAC	5000	SF	5.50	27,500
ELECTRICAL/INSTRUMENTATION WIRING	5000	SF	20.00	100,000
FIRE PROTECTION	5000	SF	5.00	25,000
FURNISHINGS	5000	SF	2.00	10,000
PARKING AREA	2500	SY	15.00	37,500
ELECTRICAL SERVICE				
TAP ELECTRICAL TRANSMISSION LINE	1	LS	10000.00	10,000
UTILITY POLES, 60' HIGH	2	EA	1250.00	2,500
500 KVA TRANSFORMER	1	LS	15500.00	15,500
SWITCHGEAR	1	LS	70000.00	70,000
OVERHEAD CABLE	200	LF	10.00	2,000
BURIED 3/4" DIA WATER LINE	75	LF	20.00	1,500
BURIED 6" DIA INFLUENT LINE	75	LF	25.00	1,875
BURIED 10" DIA EFFLUENT LINE	75	LF	45.00	3,375
UNDEVELOPED DESIGN DETAILS ~20%				124,750
TOTAL AIR STRIPPING/CARBON ADSORPTION TREATMENT FACILITY CONSTRUCTION				$749,000

DATE: 03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION GW-4 IRM AND AIR STRIPPING/CARBON ADSORPTION
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION GW-4 IRM AND AIR STRIPPING/CARBON ADSORPTION

PROCESS EQUIPMENT DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
FILTER ASSEMBLY	1	LS	20000.00	$20,000
INFLUENT EQUALIZATION TANK, 5000 GAL	1	EA	8500.00	8,500
CARBON ADSORPTION UNIT, 2 - 20000 LB	2	EA	300000.00	600,000
INITIAL CARBON CHARGE	4	EA	15500.00	62,000
AIR STRIPPING TOWER, PUMP, BLOWER	3	EA	65000.00	195,000
VAPOR PHASE CARBON SYSTEM,	ANNUALIZED COSTS FOR LEASED UNITS			
25 KW HEATER	3	EA	12500.00	37,500
AIR STRIPPER SUMP, 5000 GAL	1	EA	8500.00	8,500
AIR STRPR SUMP PUMP, 1500 GPM, 30 HP	1	EA	10000.00	10,000
AIR STRPR SUMP PUMP, 2000 GPM, 65 HP	1	EA	15000.00	15,000
EFFLUENT TANK, 5000 GAL	1	EA	8500.00	8,500
EFFLUENT PUMP, 1500 GPM, 165 HP	1	EA	27000.00	27,000
EFFLUENT PUMP, 2000 GPM, 220 HP	1	EA	30000.00	30,000
PIPING, FITTINGS, VALVES BETWEEN COMPONENTS				
10" DIA PVC	350	LF	130.00	45,500
8" DIA PVC	150	LF	75.00	11,250
INSTRUMENTATION				
FLOW TRANSMITTER - 10" DIA	4	EA	10000.00	40,000
PRESSURE TRANSMITTER	9	EA	1500.00	13,500
LEVEL SWITCH	12	EA	2500.00	30,000
PROGRAMMABLE LOGIC CONTROLLER	1	LS	25000.00	25,000
PANEL MTD INDICATORS	4	EA	1000.00	4,000
PANEL MTD RECORDER, 3 PEN	1	EA	7500.00	7,500
ANNUNCIATOR	1	LS	10000.00	10,000
CONTROL PANEL	1	LS	35000.00	35,000
AIR COMPRESSOR	1	LS	65000.00	65,000
UNDEVELOPED DESIGN DETAILS ~20%				262,250
TOTAL PRECESS EQUIPMENT				$1,571,000

DATE: 03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION GW-4 IRM AND AIR STRIPPING/CARBON ADSORPTION
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION GW-4 IRM AND AIR STRIPPING/CARBON ADSORPTION
EFFLUENT PIPE & IRM FACILITY MODIFICATION

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
EFFLUENT PIPE MODIFICATIONS				
SPLICE IN 8-FT SECTIONS OF 10" DIA PIP AT MANHOLE	3	EA	2000.00	$6,000
INSTALL AIR/VACUUM RELIEF VALVE				
IN EXISTING MANHOLE	1	EA	750.00	750
IN NEW MANHOLE	1	EA	3250.00	3,250
UNDEVELOPED DESIGN DETAILS ~20%				2,000
TOTAL EFFLUENT PIPE MODIFICATION				$12,000
IRM FACILITY MODIFICATIONS				
INFLUENT TRANSFER PUMP, 500 GPM, 25 HP	1	EA	6500.00	$6,500
EFFLUENT TRANSFER PUMP, 500 GPM, 55 HP	1	EA	11500.00	11,500
MOTOR STARTER, SIZE 2 - RE-USE EXISTING				
MOTOR STARTER, SIZE 4 REPLACES SIZE 3	1	EA	4000.00	4,000
INFLUENT TRANSFER PUMP POWER CIRCUIT - RE-USE EXISTING				
EFFLUENT TRANSFER PUMP POWER CIRCUIT 4#2 & 1.5" RGS	100	LF	15.00	1,500
UNDEVELOPED DESIGN DETAILS ~20%				4,500
TOTAL IRM FACILITY MODIFICATIONS				$28,000
OPERATING & MAINTENANCE COSTS (WELLS REPLACED IN YEARS 16, 32, 48)				
REPLACEMENT WELLS	2	EA	10000.00	$20,000
CONTINGENCY ~10%				2,000
TOTAL COST REPLACEMENT WELLS				$22,000

DATE:03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION GW-4 IRM AND AIR STRIPPING/CARBON ADSORPTION
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION GW-4 IRM AND AIR STRIPPING/CARBON ADSORPTION

ANNUAL O&M COSTS DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
AIR STRIPPING/CARBON ADSORPTION TREATMENT FACILITY OPERATION				
PUMPING ELECTRICAL LOAD - 260 KW	2277600	KWHR	0.04	$91,104
AQUEOUS CARBON REPLACEMENT	3	TIMES	15500.00	46,500
VAPOR PHASE CARBON REPLACEMENT				
ANNUALIZED REPLACEMENT COST YEARS 0,6,12,etc	1	LS	11,850.00	11,850
MONTHLY LEASE FEE	12	MON	6900.00	82,800
LABOR - 20 HR/WK	1040	MNHR	40.00	41,600
BUILDING LIGHTS & POWER - 30 KW	262800	KWHR	0.04	10,512
SAMPLING (3 SAMPLES BIWEEKLY)				
EPA MTD 624 VOAs	78	EA	275.00	21,450
EPA MTD 625 SVOAs	78	EA	518.00	40,404
INORGANICS	78	EA	163.00	12,714
IRM FACILITY OPERATION				
PUMPING ELECTRICAL LOAD - 85 KW	744600	KWHR	0.04	29,784
CARBON REPLACEMENT	6	TIMES	15500.00	93,000
LABOR - 20 HR/WK	1040	MNHR	40.00	41,600
BUILDING LIGHTS & POWER - 11 KW	96360	KWHR	0.04	3,854
SAMPLING (4 SAMPLES BIWEEKLY)				
EPA MTD 624 VOAs	104	EA	275.00	28,600
EPA MTD 625 SVOAs	104	EA	518.00	53,872
INORGANICS	104	EA	163.00	16,952
TREATED GROUNDWATER DISCHARGE SAMPLING (1 SAMPLE TWICE PER MONTH)				
EPA MTD 624 VOAs	24	EA	275.00	6,600
EPA MTD 625 SVOAs	24	EA	518.00	12,432
INORGANICS	24	EA	163.00	3,912
GROUNDWATER MONITORING	1	LS	345000.00	345,000
MAINTENANCE COSTS @ 5% OF TOTAL CONSTRUCTION COST	5.00%		4680833.33	234,042
UNDEVELOPED DESIGN DETAILS ~20%				245,418
TOTAL ANNUAL O&M COSTS				$1,474,000

DATE:03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION GW-5 IRM AND RESIN ADSORPTION
JOB # 6853-09
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION GW-5 IRM AND RESIN ADSORPTION
COST SUMMARY TABLE

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
DIRECT COST OF OPTION GW-5 IRM AND RESIN ADSORPTION				
SITE PREPARATION AND MOB/DEMOB				$402,000
EXTRACTION SYSTEM CONSTRUCTION				2,855,000
RESIN ADSORPTION TREATMENT FACILITY CONSTRUCTION				545,000
PROCESS EQUIPMENT				3,069,000
EFFLUENT PIPE MODIFICATION				12,000
IRM FACILITY MODIFICATION				28,000
TREATABILITY TESTING				48,000
TOTAL DIRECT COST OF OPTION GW-5 IRM AND RESIN ADSORPTION				$6,959,000
INDIRECT COST OF OPTION GW-5 IRM AND RESIN ADSORPTION				
HEALTH AND SAFETY			5.00%	$348,000
LEGAL, ADMIN, PERMITTING			5.00%	348,000
ENGINEERING			10.00%	696,000
SERVICES DURING CONSTRUCTION			10.00%	696,000
TOTAL INDIRECT COST OF OPTION GW-5 IRM AND RESIN ADSORPTION				$2,088,000
TOTAL CAPITAL (DIRECT + INDIRECT) COST				$9,047,000
OPERATING AND MAINTENANCE COSTS				
TOTAL COST REPLACEMENT WELLS				$22,000
TOTAL PRESENT WORTH OF REPLACEMENT WELLS IN YEARS 16, 32, 48 @ 5%				$17,000
TOTAL ANNUAL OPERATING AND MAINTENANCE COSTS				$1,383,000
TOTAL PRESENT WORTH OF O&M COSTS (5% FOR SIXTY-FIVE YEARS)				$26,500,000
TOTAL COST OF OPTION GW-5 IRM AND RESIN ADSORPTION				$35,564,000

DATE: 03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION GW-5 IRM AND RESIN ADSORPTION
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION GW-5 IRM AND RESIN ADSORPTION
SITE PREPARATION AND MOB/DEMOB

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
EQUIPMENT (IN OR OUT)				
FRONT END LOADER	2	EA	520.00	$1,040
DUMP TRUCKS	4	EA	260.00	1,040
BACKHOE	2	EA	520.00	1,040
OFFICE TRAILER	6	MON	155.00	930
STORAGE TRAILER (2 EA)	12	MON	155.00	1,860
TRAILER SET-UP & DELIVERY, REMOVAL	3	EA	310.00	930
TOILET (2 EA*6 MON/EA*4.2 WK/MON)	50	WK	25.00	1,250
WATER CLR (2EA*6MON/EA*4.2WK/MON)	50	WK	25.00	1,250
WATER (50 WK * 5 DAY/WK)	250	DAY	15.00	3,750
TELEPHONE SERVICE	6	MON	520.00	3,120
ELECTRICAL HOOK-UP	1	LS	2500.00	2,500
ELECTRICAL POWER	6	MON	300.00	1,800
PICK-UP (2 EA * 6 MON/EA)	12	MON	1035.00	12,420
OFFICE EQUIPMENT	6	MON	1035.00	6,210
PUMPS, TOOLS MINOR EQUIPMENT	1	LS	5000.00	5,000
CLEAR AND GRUB STUMPS - MEDIUM TREES	0.5	AC	6375.00	3,188
STAGING & PARKING				
12" GRAVEL	2420	SY	6.50	15,730
COVERED STAGING AREA	2400	SF	35.00	84,000
LABORER (2 MEN*10 DAY/MAN*8 HR/DAY)	160	MNHR	30.50	4,880
CARPENTER (2 MEN*10 DAY/MAN*8 HR/DAY)	160	MNHR	39.00	6,240
ELECTRICIAN (2 MEN*10 DAY/MAN*8 HR/DAY	160	MNHR	42.50	6,800
SITE SUPERINTENDANT (6 MON*210 HR/MON)	1260	MNHR	62.25	78,435
FOREMAN (6 MON * 210 HR/MON)	1260	MNHR	51.75	65,205
CLERK/TYPIST (6 MON * 168 HR/MON)	1008	MNHR	26.00	26,208
UNDEVELOPED DESIGN DETAILS ~20%				67,175
TOTAL SITE PREPARATION AND MOB/DEMOB				$402,000

DATE: 03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION GW-5 IRM AND RESIN ADSORPTION
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

JOB # 6853-09

ESTIMATOR: P. R. MARTIN

OPTION GW-5 IRM AND RESIN ADSORPTION EXTRACTION SYSTEM CONSTRUCTION DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
EXTRACTION WELLS	6	EA	36000.00	$216,000
EXTRACTION WELL PUMPS	2	EA	50000.00	100,000
	4	EA	25000.00	100,000
BURIED 6" DIA PVC FORCE MAIN	5500	LF	25.00	137,500
BURIED 10" DIA PVC FORCE MAIN	5000	LF	45.00	225,000
CONDUITS - 2 X 2, 4" DIA RGS	5500	LF	100.00	550,000
- 2 X 4, 3" DIA RGS	5000	LF	150.00	750,000
POWER WIRING - 4C-500 MCM	5500	LF	30.00	165,000
4C-300 MCM	5000	LF	20.00	100,000
INSTRUMENTATION WIRING	31000	LF	1.15	35,650
UNDEVELOPED DESIGN DETAILS ~20%				475,850
TOTAL EXTRACTION SYSTEM CONSTRUCTION				$2,855,000
TREATABILITY TESTING	1	LS	40000.00	$40,000
UNDEVELOPED DESIGN DETAILS ~20%				8,000
TOTAL TREATABILITY TESTING				$48,000

DATE: 03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION GW-5 IRM AND RESIN ADSORPTION
JOB # 6853-09

LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT

ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION GW-5 IRM AND RESIN ADSORPTION
RESIN ADSORPTION TREATMENT FACILITY CONSTRUCTION

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
PRE-ENGINEERED STRUCTURE ON CONCRETE PAD	2700	SF	57.50	$155,250
ARCHITECTURAL ITEMS	2700	SF	11.50	31,050
PLUMBING	2700	SF	4.00	10,800
HVAC	2700	SF	6.50	17,550
ELECTRICAL/INSTRUMENTATION WIRING	2700	SF	23.00	62,100
FIRE PROTECTION	2700	SF	6.00	16,200
FURNISHINGS	2700	SF	2.50	6,750
PARKING AREA	2500	SY	15.00	37,500
ELECTRICAL SERVICE				
TAP ELECTRICAL TRANSMISSION LINE	1	LS	10000.00	10,000
UTILITY POLES, 60' HIGH	2	EA	1250.00	2,500
750 KVA TRANSFORMER	1	LS	19000.00	19,000
SWITCHGEAR	1	LS	75000.00	75,000
OVERHEAD CABLE	200	LF	12.00	2,400
BURIED 1" DIA WATER LINE	150	LF	21.00	3,150
BURIED 6" DIA INFLUENT LINE	75	LF	25.00	1,875
BURIED 10" DIA EFFLUENT LINE	75	LF	45.00	3,375
UNDEVELOPED DESIGN DETAILS ~20%				90,500
TOTAL RESIN ADSORPTION TREATMENT FACILITY CONSTRUCTION				$545,000

DATE:03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION GW-5 IRM AND RESIN ADSORPTION
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION GW-5 IRM AND RESIN ADSORPTION
PROCESS EQUIPMENT

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
INFLUENT EQUALIZATION TANK, 5000 GAL	1	EA	8500.00	$8,500
INFLUENT TRANSFER PUMP, 1500 GPM, 150	1	EA	20000.00	20,000
INFLUENT TRANSFER PUMP, 2000 GPM, 350	1	EA	40000.00	40,000
RESIN ADSORPTION SYSTEM				
ADSORBERS	1	LS	550000.00	550,000
ADSORBENT	1	LS	950000.00	950,000
PRE-FILTER	1	LS	100000.00	100,000
STEAM BOILER	1	LS	200000.00	200,000
SEPARATOR, CONDENSER, PIPING	1	LS	300000.00	300,000
SUPER LOADER	1	LS	160000.00	160,000
EFFLUENT TANK, 5000 GAL	1	EA	8500.00	8,500
EFFLUENT PUMP, 1500 GPM, 165 HP	1	EA	27000.00	27,000
EFFLUENT PUMP, 2000 GPM, 220 HP	1	EA	30000.00	30,000
PIPING, FITTINGS, VALVES BETWEEN COMPONENTS				
10" DIA PVC	250	LF	130.00	32,500
INSTRUMENTATION				
FLOW TRANSMITTER - 10" DIA	3	EA	10000.00	30,000
PRESSURE TRANSMITTER	1	EA	1500.00	1,500
LEVEL SWITCH	6	EA	2500.00	15,000
PROGRAMMABLE LOGIC CONTROLLER	1	LS	25000.00	25,000
PANEL MTD INDICATORS	3	EA	1000.00	3,000
PANEL MTD RECORDER, 3 PEN	1	EA	5000.00	5,000
ANNUNCIATOR	1	LS	10000.00	10,000
CONTROL PANEL	1	LS	35000.00	35,000
AIR COMPRESSOR	1	LS	6500.00	6,500
UNDEVELOPED DESIGN DETAILS ~20%				511,500
TOTAL PRECESS EQUIPMENT				$3,069,000

DATE: 03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION GW-5 IRM AND RESIN ADSORPTION
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION GW-5 IRM AND RESIN ADSORPTION EFFLUENT PIPE & IRM FACILITY MODIFICATION DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
EFFLUENT PIPE MODIFICATIONS				
SPLICE IN 8-FT SECTIONS OF 10" DIA PIP AT MANHOLE	3	EA	2000.00	$6,000
INSTALL AIR/VACUUM RELIEF VALVE				
IN EXISTING MANHOLE	1	EA	750.00	750
IN NEW MANHOLE	1	EA	3250.00	3,250
UNDEVELOPED DESIGN DETAILS ~20%				2,000
TOTAL EFFLUENT PIPE MODIFICATION				$12,000
IRM FACILITY MODIFICATIONS				
INFLUENT TRANSFER PUMP, 500 GPM, 25 HP	1	EA	6500.00	$6,500
EFFLUENT TRANSFER PUMP, 500 GPM, 55 HP	1	EA	11500.00	11,500
MOTOR STARTER, SIZE 2 - RE-USE EXISTING				
MOTOR STARTER, SIZE 4 REPLACES SIZE 3	1	EA	4000.00	4,000
INFLUENT TRANSFER PUMP POWER CIRCUIT - RE-USE EXISTING				
EFFLUENT TRANSFER PUMP POWER CIRCUIT 4#2 & 1.5" RGS	100	LF	15.00	1,500
UNDEVELOPED DESIGN DETAILS ~20%				4,500
TOTAL IRM FACILITY MODIFICATIONS				$28,000
OPERATING & MAINTENANCE COSTS (WELLS REPLACED IN YEARS 16, 32, 48)				
REPLACEMENT WELLS	2	EA	10000.00	$20,000
CONTINGENCY ~10%				2,000
TOTAL COST REPLACEMENT WELLS				$22,000

DATE: 03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION GW-5 IRM AND RESIN ADSORPTION
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION GW-5 IRM AND RESIN ADSORPTION
ANNUAL O&M COSTS

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
RESIN ADSORPTION TREATMENT FACILITY OPERATION				
BUILDING POWER & LIGHTS - 16.2 KW	141912	KWHR	0.04	$5,676
PUMPING COST	1	LS	84430.00	84,430
LABOR - 20 HR/WK	1040	MNHR	40.00	41,600
REGENERATION COSTS	1	LS	20400.00	20,400
SAMPLING (3 SAMPLES BIWEEKLY)				
EPA MTD 624 VOAs	78	EA	275.00	21,450
EPA MTD 625 SVOAs	78	EA	518.00	40,404
INORGANICS	78	EA	163.00	12,714
IRM FACILITY OPERATION				
PUMPING ELECTRICAL LOAD - 85 KW	744600	KWHR	0.04	29,784
CARBON REPLACEMENT	6	TIMES	15500.00	93,000
LABOR - 20 HR/WK	1040	MNHR	40.00	41,600
BUILDING POWER & LIGHTS - 11 KW	96360	KWHR	0.04	3,854
SAMPLING (4 SAMPLES BIWEEKLY)				
EPA MTD 624 VOAs	104	EA	275.00	28,600
EPA MTD 625 SVOAs	104	EA	518.00	53,872
INORGANICS	104	EA	163.00	16,952
TREATED GROUNDWATER DISCHARGE SAMPLING (1 SAMPLE TWICE PER MONTH)				
EPA MTD 624 VOAs	24	EA	275.00	6,600
EPA MTD 625 SVOAs	24	EA	518.00	12,432
INORGANICS	24	EA	163.00	3,912
GROUNDWATER MONITORING	1	LS	345000.00	345,000
MAINTENANCE COSTS @ 5% OF TOTAL CONSTRUCTION COST	5.00%		5799166.67	289,958
UNDEVELOPED DESIGN DETAILS ~20%				230,761
TOTAL ANNUAL O&M COSTS				$1,383,000

DATE: 03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION GW-7 IRM AND UV REDUCTION/CARBON ADSORPTION
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION GW-7 IRM AND UV REDUCTION/CARBON ADSORPTION
COST SUMMARY TABLE

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
DIRECT COST OF OPTION GW-7 IRM AND UV REDUCTION/CARBON ADSORPTION				
SITE PREPARATION AND MOB/DEMOB				$402,000
EXTRACTION SYSTEM CONSTRUCTION				2,855,000
UV REDUCTION/CARBON ADSORPTION TREATMENT FACILITY CONSTRUCTION				719,000
PROCESS EQUIPMENT				2,474,000
EFFLUENT PIPE MODIFICATION				12,000
IRM FACILITY MODIFICATION				28,000
TREATABILITY TESTING				6,000
TOTAL DIRECT COST OF OPTION GW-7 IRM AND UV REDUCTION/CARBON ADSORPTION				$6,496,000
INDIRECT COST OF OPTION GW-7 IRM AND UV REDUCTION/CARBON ADSORPTION				
HEALTH AND SAFETY			5.00%	$325,000
LEGAL, ADMIN, PERMITTING			5.00%	325,000
ENGINEERING			10.00%	650,000
SERVICES DURING CONSTRUCTION			10.00%	650,000
TOTAL INDIRECT COST OF OPTION GW-7 IRM AND UV REDUCTION/CARBON ADSORPTION				$1,950,000
TOTAL CAPITAL (DIRECT + INDIRECT) COST				$8,446,000
OPERATING AND MAINTENANCE COSTS				
TOTAL COST REPLACEMENT WELLS				$22,000
TOTAL PRESENT WORTH OF REPLACEMENT WELLS IN YEAR 16, 32, 48 @ 5%				$17,000
TOTAL ANNUAL OPERATING AND MAINTENANCE COSTS				$2,056,000
TOTAL PRESENT WORTH OF O&M COSTS (5% FOR SIXTY-FIVE YEARS)				$31,606,000
TOTAL COST OF OPTION GW-7 IRM AND UV REDUCTION/CARBON ADSORPTION				$40,069,000

DATE:03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION GW-7 IRM AND UV REDUCTION/CARBON ADSORPTION
JOB # 6853-09
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION GW-7 IRM AND UV REDUCTION/CARBON ADSORPTION
SITE PREPARATION AND MOB/DEMOB

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
EQUIPMENT (IN OR OUT)				
FRONT END LOADER	2	EA	520.00	$1,040
DUMP TRUCKS	4	EA	260.00	1,040
BACKHOE	2	EA	520.00	1,040
OFFICE TRAILER	6	MON	155.00	930
STORAGE TRAILER (2 EA)	12	MON	155.00	1,860
TRAILER SET-UP & DELIVERY, REMOVAL	3	EA	310.00	930
TOILET (2 EA*6 MON/EA*4.2 WK/MON)	50	WK	25.00	1,250
WATER CLR (2EA*6MON/EA*4.2WK/MON)	50	WK	25.00	1,250
WATER (50 WK * 5 DAY/WK)	250	DAY	15.00	3,750
TELEPHONE SERVICE	6	MON	520.00	3,120
ELECTRICAL HOOK-UP	1	LS	2500.00	2,500
ELECTRICAL POWER	6	MON	300.00	1,800
PICK-UP (2 EA * 6 MON/EA)	12	MON	1035.00	12,420
OFFICE EQUIPMENT	6	MON	1035.00	6,210
PUMPS, TOOLS MINOR EQUIPMENT	1	LS	5000.00	5,000
CLEAR AND GRUB STUMPS - MEDIUM TREES	0.5	AC	6375.00	3,188
STAGING & PARKING				
12" GRAVEL	2420	SY	6.50	15,730
COVERED STAGING AREA	2400	SF	35.00	84,000
LABORER (2 MEN*10 DAY/MAN*8 HR/DAY)	160	MNHR	30.50	4,880
CARPENTER (2 MEN*10 DAY/MAN*8 HR/DAY)	160	MNHR	39.00	6,240
ELECTRICIAN (2 MEN*10 DAY/MAN*8 HR/DAY	160	MNHR	42.50	6,800
SITE SUPERINTENDANT (6 MON*210 HR/MON)	1260	MNHR	62.25	78,435
FOREMAN (6 MON * 210 HR/MON)	1260	MNHR	51.75	65,205
CLERK/TYPIST (6 MON * 168 HR/MON)	1008	MNHR	26.00	26,208
UNDEVELOPED DESIGN DETAILS ~20%				67,175
TOTAL SITE PREPARATION AND MOB/DEMOB				$402,000

DATE:03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION GW-7 IRM AND UV REDUCTION/CARBON ADSORPTION
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION GW-7 IRM AND UV REDUCTION/CARBON ADSORPTION
EXTRACTION SYSTEM CONSTRUCTION

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
EXTRACTION WELLS	6	EA	36000.00	$216,000
EXTRACTION WELL PUMPS	2	EA	50000.00	100,000
	4	EA	25000.00	100,000
BURIED 6" DIA PVC FORCE MAIN	5500	LF	25.00	137,500
BURIED 10" DIA PVC FORCE MAIN	5000	LF	45.00	225,000
CONDUITS - 2 X 2, 4" DIA RGS	5500	LF	100.00	550,000
- 2 X 4, 3" DIA RGS	5000	LF	150.00	750,000
POWER WIRING - 4C-500 MCM	5500	LF	30.00	165,000
4C-300 MCM	5000	LF	20.00	100,000
INSTRUMENTATION WIRING	31000	LF	1.15	35,650
UNDEVELOPED DESIGN DETAILS ~20%				475,850
TOTAL EXTRACTION SYSTEM CONSTRUCTION				$2,855,000

DATE: 03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION GW-7 IRM AND UV REDUCTION/CARBON ADSORPTION
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION GW-7 IRM AND UV REDUCTION/CARBON ADSORPTION
UV RED/CARBON ADSORP TREATMENT FACILITY CONSTRUCTION

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
PRE-ENGINEERED STRUCTURE ON CONCRETE PAD	4500	SF	50.00	$225,000
ARCHITECTURAL ITEMS	4500	SF	10.00	45,000
PLUMBING	4500	SF	3.50	15,750
HVAC	4500	SF	5.50	24,750
ELECTRICAL/INSTRUMENTATION	4500	SF	20.00	90,000
FIRE PROTECTION	4500	SF	5.00	22,500
FURNISHINGS	4500	SF	2.00	9,000
PARKING AREA	2500	SY	15.00	37,500
ELECTRICAL SERVICE				
TAP ELECTRICAL TRANSMISSION LINE	1	LS	10000.00	10,000
UTILITY POLES, 60' HIGH	2	EA	1250.00	2,500
1500 KVA TRANSFORMER	1	LS	27500.00	27,500
SWITCHGEAR	1	LS	80000.00	80,000
OVERHEAD CABLE	200	LF	15.00	3,000
BURIED 3/4" DIA WATER LINE	75	LF	20.00	1,500
BURIED 6" DIA INFLUENT LINE	75	LF	25.00	1,875
BURIED 10" DIA EFFLUENT LINE	75	LF	45.00	3,375
UNDEVELOPED DESIGN DETAILS ~20%				119,750
TOTAL UV REDUCTION/CARBON ADSORPTION TREATMENT FACILITY CONSTRUCTION				$719,000
TREATABILITY TESTING	1	LS	5000.00	$5,000
UNDEVELOPED DESIGN DETAILS ~20%				1,000
TOTAL TREATABILITY TESTING				$6,000

DATE:03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION GW-7 IRM AND UV REDUCTION/CARBON ADSORPTION
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION GW-7 IRM AND UV REDUCTION/CARBON ADSORPTION

PROCESS EQUIPMENT DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
FILTER ASSEMBLY	1	LS	20000.00	$20,000
INFLUENT EQUALIZATION TANK, 5000 GAL	1	EA	8500.00	8,500
INFLUENT TRANSFER PUMP, 1500 GPM, 35 H	1	EA	12500.00	12,500
INFLUENT TRANSFER PUMP, 2000 GPM, 80 H	1	EA	20000.00	20,000
UV/REDUCTION/CARBON SYSTEM	1	LS	1750000.00	1,750,000
EFFLUENT TANK, 5000 GAL	1	EA	8500.00	8,500
EFFLUENT PUMP, 1500 GPM, 165 HP	1	EA	27000.00	27,000
EFFLUENT PUMP, 2000 GPM, 220 HP	1	EA	30000.00	30,000
PIPING, FITTINGS, VALVES BETWEEN COMPONENTS				
10" DIA PVC	200	LF	130.00	26,000
8" DIA PVC	150	LF	75.00	11,250
6" DIA PVC	150	LF	55.00	8,250
INSTRUMENTATION				
FLOW TRANSMITTER - 10" DIA	3	EA	10000.00	30,000
PRESSURE TRANSMITTER	7	EA	1500.00	10,500
LEVEL SWITCH	6	EA	2500.00	15,000
PROGRAMMABLE LOGIC CONTROLLER	1	LS	25000.00	25,000
PANEL MTD INDICATORS	3	EA	1000.00	3,000
PANEL MTD RECORDER, 3 PEN	1	EA	5000.00	5,000
ANNUNCIATOR	1	LS	10000.00	10,000
CONTROL PANEL	1	LS	35000.00	35,000
AIR COMPRESSOR	1	LS	6500.00	6,500
UNDEVELOPED DESIGN DETAILS ~20%				412,000
TOTAL PRECESS EQUIPMENT				$2,474,000

DATE: 03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION GW-7 IRM AND UV REDUCTION/CARBON ADSORPTION
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION GW-7 IRM AND UV REDUCTION/CARBON ADSORPTION EFFLUENT PIPE & IRM FACILITY MODIFICATION DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
EFFLUENT PIPE MODIFICATIONS				
SPLICE IN 8-FT SECTIONS OF 10" DIA PIP AT MANHOLE	3	EA	2000.00	$6,000
INSTALL AIR/VACUUM RELIEF VALVE				
IN EXISTING MANHOLE	1	EA	750.00	750
IN NEW MANHOLE	1	EA	3250.00	3,250
UNDEVELOPED DESIGN DETAILS ~20%				2,000
TOTAL EFFLUENT PIPE MODIFICATION				$12,000
IRM FACILITY MODIFICATIONS				
INFLUENT TRANSFER PUMP, 500 GPM, 25 HP	1	EA	6500.00	$6,500
EFFLUENT TRANSFER PUMP, 500 GPM, 55 HP	1	EA	11500.00	11,500
MOTOR STARTER, SIZE 2 - RE-USE EXISTING				
MOTOR STARTER, SIZE 4 REPLACES SIZE 3	1	EA	4000.00	4,000
INFLUENT TRANSFER PUMP POWER CIRCUIT - RE-USE EXISTING				
EFFLUENT TRANSFER PUMP POWER CIRCUIT 4#2 & 1.5" RGS	100	LF	15.00	1,500
UNDEVELOPED DESIGN DETAILS ~20%				4,500
TOTAL IRM FACILITY MODIFICATIONS				$28,000
OPERATING & MAINTENANCE COSTS (WELLS REPLACED IN YEARS 16, 32, 48)				
REPLACEMENT WELLS	2	EA	10000.00	$20,000
CONTINGENCY ~10%				2,000
TOTAL COST REPLACEMENT WELLS				$22,000

DATE: 03-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION GW-7 IRM AND UV REDUCTION/CARBON ADSORPTION
LOCATION: PROPELLANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION GW-7 IRM AND UV REDUCTION/CARBON ADSORPTION

ANNUAL O&M COSTS DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
UV/REDUCTION/CARBON ADSORPTION TREATMENT FACILITY OPERATION				
ANNUAL O&M COSTS (LAMPS, ADDITIVES, PARTS, LABOR)	788400	MGAL	0.81	$638,604
PUMPING ELECTRICAL LOAD - 240 KW	2102400	KWHR	0.04	84,096
SAMPLING (3 SAMPLES BIWEEKLY)				
EPA MTD 624 VOAs	78	EA	275.00	21,450
EPA MTD 625 SVOAs	78	EA	518.00	40,404
INORGANICS	78	EA	163.00	12,714
BUILDING LIGHTS & POWER - 27 KW	236520	KWHR	0.04	9,461
IRM FACILITY OPERATION				
PUMPING ELECTRICAL LOAD - 85 KW	744600	KWHR	0.04	29,784
CARBON REPLACEMENT	6	TIMES	15500.00	93,000
LABOR - 20 HR/WK	1040	MNHR	40.00	41,600
BUILDING LIGHTS & POWER - 11 KW	96360	KWHR	0.04	3,854
SAMPLING (4 SAMPLES BIWEEKLY)				
EPA MTD 624 VOAs	104	EA	275.00	28,600
EPA MTD 625 SVOAs	104	EA	518.00	53,872
INORGANICS	104	EA	163.00	16,952
TREATED GROUNDWATER DISCHARGE SAMPLING (1 SAMPLE TWICE PER MONTH)				
EPA MTD 624 VOAs	24	EA	275.00	6,600
EPA MTD 625 SVOAs	24	EA	518.00	12,432
INORGANICS	24	EA	163.00	3,912
GROUNDWATER MONITORING	1	LS	345000.00	345,000
MAINTENANCE COSTS @ 5% OF TOTAL CONSTRUCTION COST	5.00%		5413333.33	270,667
UNDEVELOPED DESIGN DETAILS ~20%				342,998
TOTAL ANNUAL O&M COSTS				$2,056,000

APPENDIX D.6

MATERIAL USAGE: GROUNDWATER ALTERNATIVES

PROPELLANT BURNING GROUND

PROJECT Estimate of Groundwater Remediation Time for PBG Plume - Batch Flush Model USEPA	COMP. BY	JOB NO.
	CHK. BY JSM	DATE 3/30/93

Conceptual Setting: 4 extraction wells at base boundary (2000 gpm total) and two source control wells

Avg. GW flow velocity under pumping conditions = 350 ft/yr (faster near extraction wells)

Assume source has been removed, and that the following are maximum concs. of COC's in groundwater at the PBG / Racetrack:

CCL4	150 ug/l
TRCLE	150 ug/l
CHCL3	50 ug/l
26DNT	5 ug/l

Following memo from R. Lewis to C. Rossoll / Hydrogeo Discipline dated 5/18/92, the USEPA batch flushing model is used below to assist in estimating groundwater clean-up times.

The number of pore volumes required to lower the dissolved concentration from an initial value C_i to a target level C_s is:

$$PV = -\frac{1}{\ln[1+(n/\rho_b K_{oc} f_{oc})]} \ln\left(\frac{C_s}{C_i}\right)$$

where ρ_b = soil bulk density

K_{oc} = organic carbon partition coefficient of the contaminant

f_{oc} = organic carbon fraction in the aquifer

n = porosity

Assume: $\rho_b = 2.0$ g/ml (Freeze & Cherry, 1979)

$n = 0.3$

K_{oc} (ml/g): $\frac{CCL4}{110}$ $\frac{TRCLE}{126}$ $\frac{CHCL3}{44}$ $\frac{26DNT}{92}$

FORM 00.01 REV. 4/81

ABB Environmental Services, Inc.

PROJECT	COMP. BY DRP	JOB NO. 6853-09
	CHK. BY JSM	DATE 3/30/93

f_{oc} is estimated to be less than 0.003 (see section 11.4.5 of Draft Final RI).

Let's assume an f_{oc} range of 0.001 to 0.0001.

CCL4 : $C_i = 150\ \mu g/l$
$C_s = 5\ \mu g/l$ (WES)

$f_{oc} = 0.001$: $PV = -\dfrac{1}{\ln[1+(0.3/2.0\times110\times0.001)]}\ln\left(\dfrac{5}{150}\right)$
$= 4.0$ flushes

$f_{oc} = 0.0001$: $PV = -\dfrac{1}{\ln[1+(0.3/2.0\times110\times0.0001)]}\ln\left(\dfrac{5}{150}\right)$
$= 1.3$ flushes

TRCLE : $C_i = 150\ \mu g/l$
$C_s = 5\ \mu g/l$ (WES)

$f_{oc}=0.001$: PV = 4.3 flushes

$f_{oc}=0.0001$: PV = 1.3 flushes

CHCL3 : $C_i = 50\ \mu g/l$
$C_s = 6\ \mu g/l$ (WES)

$f_{oc}=0.001$: PV = 2.3 flushes

$f_{oc}=0.0001$: PV = 1.0 flushes

26DNT : $C_i = 5\ \mu g/l$
$C_s = 0.05\ \mu g/l$

$f_{oc}=0.001$: PV = 4.8 flushes

$f_{oc}=0.0001$: PV = 1.6 flushes

PV range ~~for~~ f_{oc} of 0.001 is 2.3 to 4.8 flushes.

Average of all PV values is 2.6 flushes

PROJECT	COMP. BY	JOB NO.
	DRP	6853-09
	CHK. BY	DATE
	JSM	3/30/93

The natural travel time from the racetrack area to the southern base boundary has been estimated using the numerical model described in the Draft Final RI Report (the Propellant Burning Ground Model). See attached figure for an estimate of groundwater travel times under steady-state pumping conditions in the racetrack area (530 gpm total from 21 wells) and at the southern base boundary (1475 gpm total from 4 wells).

Travel Time $\cong$ 18 years

The estimated time to clean-up of the contaminated groundwater for:

PV = 2.3 flushes : (2.3)(18 yrs.) $\cong$ 41 years
PV = 4.8 flushes : (4.8)(18 yrs.) $\cong$ 86 years

Notes on Approach and Calculations:

1) The number of pore volumes (PV) to be removed depends on whether groundwater flow velocities during remediation are too rapid to allow contaminant levels to build up to equilibrium concentrations locally (i.e., desorption of contaminants from the aquifer soils may be the rate-limiting step in removal of contaminants from the aquifer).

2) Dispersive transport effects are not considered in this approach.

3) The batch flush model assumes there are no continuing sources of contamination (i.e., source removal actions have been or will be taken).

4) The use of K_d (=K_{oc}*f_{oc}) implies that the adsorption/desorption isotherm is linear.

PROJECT BAAP FS TDH CALCS; BOUNDARY CONTROL EXTRACTION WELL TO TREATMENT FAC	COMP. BY JSM	JOB NO. 6853-09
	CHK BY MPM	DATE 4/26/93

WILLIAMS & HAZEN: (Assume plastic pipe)

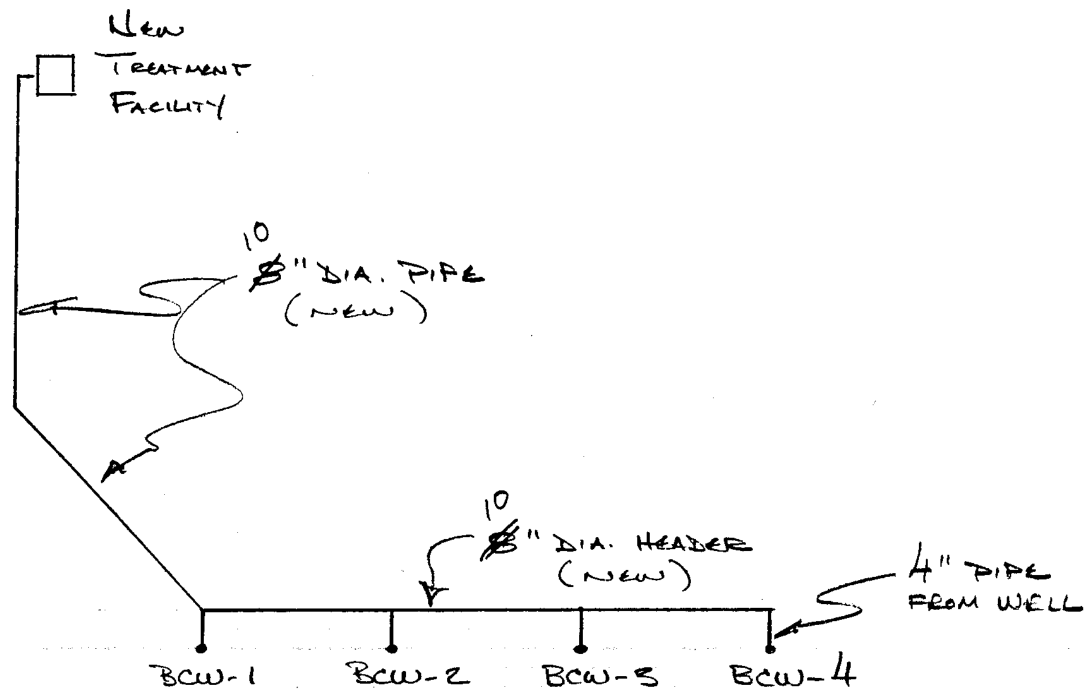
$$f = 0.2083\left(\frac{100}{C}\right)^{1.85}\frac{q^{1.85}}{d^{4.8655}}$$

f = FRICTION HEAD PER 100 FT OF PIPE (FEET)

d = I.D. OF PIPE (INCHES)

q = FLOW (GPM)

C = CONSTANT FOR SURFACE ROUGHNESS



BCW-4 TDH

4" PIPE: LINEAR LENGTH 150' (PUMP TO WELLHEAD)
+ EQUIVALENT + 10' (WELLHEAD 10 ~~8~~" DIA. HEADER)
+ 2.68 (GATE VALVE)
~~+ 22 15.2~~ 2x90° EL) (~~4~~")
~~25.1 + 20.1 (STD TEE, BRANCH FLOW)(10")~~
~~198'~~ 182.88 (90° elbow)
≈ ~~200~~ 185

Ref: Camerons Hydraulic Data Handbook

$$f = 0.2083\left(\frac{100}{130}\right)^{1.85}\frac{375^{1.85}}{4^{4.8655}} = 8.72'/100' \text{ pipe}$$

PROJECT BAAP FS TDH CALCS EXTRACTION WELL TO TREATMENT FAC.	COMP. BY JSM	JOB NO. 6853-09
	CHK BY MPM	DATE 4/26/93

⇒ FOR 200' OF PIPE f_{TOTAL} = 8.72 × ~~2~~ 1.85
= ~~17.44~~ 16.13 ' ≃ 20' ✓

10" PIPE : LINEAR LENGTH + EQUIVALENT

5,000' (4" JUNCTION TO FACILITY)
+50' (3 × FLOW THROUGH TEES) 10" ⇒ 3×16.7
+27" (2 × 45° ELBOWS) 2×13.4
+100' (4 × 90° ELBOWS IN FACILITY) 4×25.4
+100' (2 × BRANCH FLOW TEES) 2×50.1
+35' (2.3 × 15 PSI FOR DROP ACROSS FILTER)
5,312

$$f = 0.2083\left(\frac{100}{130}\right)^{1.85}\frac{1{,}500^{1.85}}{10^{4.8655}} = 1.3'/100' \text{ OF PIPE}$$

⇒ FOR 5,312' OF PIPE f_{TOTAL} = 1.3 × 53.12
= 69'
≃ 70' ✓

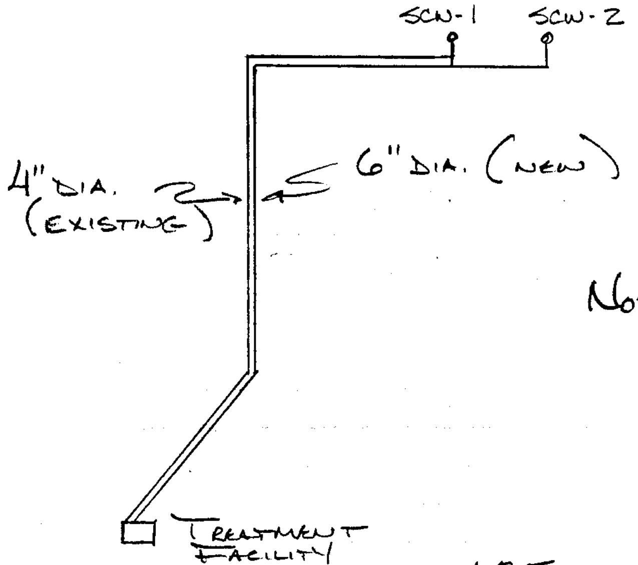
STATIC HEAD :

Δh = 95' (WATER TABLE TO GROUND SURFACE)
+44' (WELLHEAD TO TREATMENT FACILITY)
139'
≃ 140'

⇒ TOTAL HEAD LOSS = 140' + 70' + 20'
= 230' → PUMP HP ~ 30 (75% eff.)

⇒ GRUNDFOS 375S400-6DS (40 HP)
(DEEP SET STAINLESS STEEL SUBMERSIBLE PUMP)

PROJECT BAAP FS TDH CALCS ; SOURCE CONTROL EXTRACTION WELL TO TREATMENT FACILITY	COMP. BY JSM	JOB NO. 6853-09
	CHK BY MPM	DATE 4/26/93



NOTE: CACULATIONS ARE FOR ONE SOURCE CONTROL PUMPING FUNCTIONING IN IT'S BACK-UP CAPACITY (i.e., BACK-UP @ 500 GPM VS. NORMAL @ 250 GPM).

$$f = 0.2083\left(\frac{100}{130}\right)^{1.85}\frac{500^{1.85}}{6^{4.8655}} = 2.1'/100' \text{ OF PIPE}$$

6" PIPE: LINEAR LENGTH + EQUIVALENT

133'	(PUMP TO WELLHEAD)
+ 5,500'	(WELLHEAD TO FACILITY)
+ 61	(4 x 90° ELBOWS - WELLHEAD TO FACILITY)
+ 4	(GATE VALVE)
+ 61	(4 x 90° ELBOWS - IN FACILITY)
+ 61	(2 x BRANCH FLOW TEES)
+ 35	(2.3 x 15 PSI FOR DROP ACROSS FILTER)
5,855	

$\Rightarrow$ FOR 5,855' OF PIPE $f_{TOTAL} = 2.1' \times 58.55$
$= 123'$

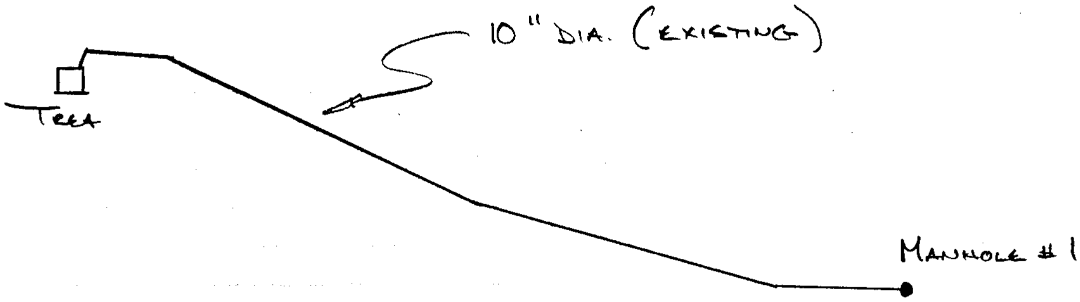
STATIC HEAD:

$\Delta h =$ 100' (WATER TABLE TO GROUND SURFACE)
− 40' (WELLHEAD TO TREATMENT FACILITY)
60'

$\Rightarrow$ TDH = 123' + 60'
= 183' $\longrightarrow$ ROUND UP TO 200'
$\longrightarrow$ PUMP HP ~ 35

$\Rightarrow$ GRUNDFOS 375S500-8DS (50 HP)
(DEEP SET STAINLESS STEEL SUBMERSIBLE PUMP)

PROJECT BAAP FS TDH CALCS ; EFFLUENT LINE TREATMENT FACILITY TO MANHOLE #1	COMP. BY JSM CHK BY MPM	JOB NO. 6853 09 DATE 4/28/93



$$f = 0.2083 \left(\frac{100}{130}\right)^{1.85} \frac{2{,}000^{1.85}}{10^{4.8655}} = 2.2' / 100' \text{ OF PIPE}$$

10" PIPE : LINEAR LENGTH + EQUIVALENT

$$\begin{array}{rl} 3{,}500' & \text{(TREATMENT BUILDING TO MANHOLE \#1)} \\ + \quad 75' & (3 \times 90° \text{ ELBOWS}) \\ + \quad \cancel{32}\ 40' & (3 \times 45° \text{ ELBOWS}) \\ \hline \cancel{3607}'\ 3615 & \\ \approx 3{,}600 & \end{array}$$

$\Rightarrow$ FOR 3,600' OF PIPE $f_{TOTAL} = 2.2' \times 36$
$= 80'$

STATIC HEAD :

$\Delta h = 50'$ (TREATMENT BUILDING TO MANHOLE #1)

$\Rightarrow$ TDH = 80' + 50' = 130' $\rightarrow$ ROUND UP TO 150'

TDH FOR 14,000' OF EFFLUENT PIPE :

FOR 14,000' OF PIPE $f_{TOTAL} = 2.2' \times 140$
$= 308$

STATIC HEAD :

$$\begin{array}{rl} \Delta h = -40 & \text{(TREATMENT BUILDING TO LAKE WISCONSIN)} \\ + \quad 50 & \text{(ASSUMED FOR OUTFALL / DIFFUSER)} \\ \hline 10' & \end{array}$$

$\Rightarrow$ TDH = 318 $\rightarrow$ ROUND UP TO 325'

PROJECT BAAF FS BAAF GW DISCHARGE COST COMPARISON	COMP. BY JSM CHK. BY GNP	JOB NO. 6853-09 DATE 4/28/93

OPTION 1 (PUMPING DIRECTLY TO LAKE WISCONSIN)

- MODEL 3410 SINGLE STAGE, DOUBLE SUCTION PUMP (GOULDS) (L 8x10-17) EFFICIENCY = 82%

- TDH FOR 14,000' OF EFFLUENT PIPE

$$f = 0.2083\left(\frac{100}{130}\right)^{1.85}\frac{2{,}000^{1.85}}{10^{4.8655}}$$

$f = 2.2'/100'$

STATIC HEAD:
$\Delta h = -40'$ (TREATMENT BUILDING TO LAKE WISCONSIN)
$+50'$ (ASSUMED FOR OUTFALL/DIFFUSER)

$\Rightarrow$ TDH = $140 \times 2.2' + 10' = 318'$
ROUND UP TO 325'

$\Rightarrow$ HP REQUIREMENT = $\dfrac{325 \times 2000}{0.82 \times 3960}$ = 200 HP

- ANNUAL OPERATING COST
$8{,}760\ \dfrac{(200)(0.746)(0.04)}{0.9} = \$58{,}088/YR$

- CAPITAL COST FOR PUMPS = \$30,000
- PRESENT WORTH @ 5% DISCOUNT RATE OVER 65 YEARS
\$30,000 + \$58,088 x 19.161 ≈ \$1,143,000 ✓

OPTION 2 (PUMPING TO TOP OF HILL, GRAVITY FLOW TO LAKE)

- MODEL 3196 ANSI (6x8-13 XLT) EFFICIENCY = 82%
- TDH FOR 3,600' OF EFFLUENT PIPE
$f = 2.2'/100'$ (SEE ABOVE)

STATIC HEAD:
$\Delta h = 50'$ (TREATMENT BUILDING TO LAKE WISCONSIN)

$\Rightarrow$ TDH = $36 \times 2.2' + 50' = 129.2'$
ROUND UP TO 130'

$\Rightarrow$ HP REQUIREMENT = $\dfrac{130 \times 2{,}000}{0.82 \times 3960}$ = 80 HP

PROJECT BAAP FS BAAP GW DISCHARGE COST COMPARISON	COMP. BY JSM CHK. BY SNP	JOB NO. 6853-09 DATE 4/28/93

- ANNUAL OPERATING COST

$$8{,}760\,\frac{(80)(0.746)(0.04)}{(0.9)} = \$23{,}235/\text{YR}$$

- CAPITAL COST FOR PUMPS = \$20,000
  " " " 10,400' OF PIPE TRENCH = \$728,000
  (\$70/FT FOR 12" DIA. PIPE (SEE PAGE 3))

- PRESENT VALUE @ 5% DISCOUNT RATE OVER 65 YEARS

$$\$20{,}000 + \$728{,}000 + \$23{,}235 \times 19.161 \approx \$1{,}193{,}000$$ ✓

FORM 00.01 REV. 4/81

ABB Environmental Services, Inc.

PROJECT	COMP. BY	JOB NO.
BADGER FS BAAP GW DISCHARGE COST COMPARISON	RHS	6853-09
	CHK. BY JSM	DATE 4/28/93

ESTIMATE CAPACITY 10" Ø OUTFALL

Est. Slope = (880' - 800') ÷ 10,500' = 0.0076 %

Roughness Coefficient 'N' = 0.013

10" Ø @ 0.76/100' will carry 850 gpm when full

2 × 10" Ø will carry 1200 gpm

10" Ø + 12" Ø

12" Ø @ 0.76/100' = 1400 gpm

10" Ø = 850 gpm

TOTAL = 2250 gpm

Install 16" Ø = 2,950 gpm

PROJECT	COMP. BY	JOB NO.
BAAP FS PUMP REQUIREMENTS FOR NEW TREATMENT FACILITY	JSM	6853-09
	CHK. BY MPM	DATE 4/16/93

ALTERNATIVE PBG-GW2: IRM & CARBON

INFLUENT TRANSFER PUMP:

PRESSURE DROP ACROSS CARBON SYSTEM @ 2,000 GPM = 27 PSI

$\Rightarrow$ HEAD LOSS = 27 × 2.31 = 62.4'

ADD SAFETY FACTOR OF 1.5 ~ 95'

$\Rightarrow$ HORSEPOWER @ 2,000 GPM $= \dfrac{(2{,}000)(95)}{(0.75)(3960)}$

HP ~ 65

PRESSURE DROP ACROSS CARBON SYSTEM @ 1,500 GPM = 16 PSI

$\Rightarrow$ HEAD LOSS = 16 × 2.31 = 36.96'

ADD SAFETY FACTOR OF 1.5 ~ 55'

$\Rightarrow$ HORSEPOWER @ 1,500 GPM $= \dfrac{(1{,}500)(55')}{(0.75)(3960)}$

HP ~ 30

ALTERNATIVE PBG-GW4: IRM & AIR STRIP-CARBON

INFLUENT TRANSFER PUMP:

ASSUME STATIC HEAD ~ 50'

$\Rightarrow$ TDH OF 70' (INCLUDING FRICTION HEAD) (assumed) @ 2,000 GPM

$\Rightarrow$ HORSEPOWER $= \dfrac{(2{,}000)(70)}{(0.75)(3960)}$

HP ~ 50

TDH ~ 60' (assumed) @ 1,500 GPM

$\Rightarrow$ HORSEPOWER $= \dfrac{(1{,}500)(60)}{(0.75)(3960)}$

HP ~ 30

AIR STRIPPER SUMP PUMP:

TDH ~ 95' @ 2,000 GPM ACROSS CARBON $\Rightarrow$ HP ~ 65 (SEE ABOVE)

TDH ~ 55' @ 1,500 GPM ACROSS CARBON $\Rightarrow$ HP ~ 30 (SEE ABOVE)

PROJECT BAAP FS PUMP REQUIREMENTS FOR NEW FACILITY	COMP. BY JSM	JOB NO. 6853-09
	CHK. BY MPM	DATE 4/16/93

ALTERNATIVE PBG-GW5 IRM & RESIN ADSORPTION
INFLUENT TRANSFER PUMP:

PRESSURE DROP ACROSS RESIN SYSTEM @ 2,000 GPM = 510'
(BACKED-OUT FROM ROHM & HAAS COST DATA)

$$\Rightarrow \text{HORSEPOWER @ 2,000 GPM} = \frac{(2{,}000)(510)}{(0.75)(3960)}$$

HP ~ 350

PRESSURE DROP @ 1,500 GPM = 300' (BACKED-OUT)

$$\Rightarrow \text{HORSEPOWER @ 1,500 GPM} = \frac{(1{,}500\ \text{GPM})(300)}{(0.75)(3960)}$$

HP ~ 150

ALTERNATIVE PBG-GW7 IRM & UV/REDUCTION-CARBON
INFLUENT TRANSFER PUMP:

PRESSURE DROP ACROSS UV/REDUCTION & CARBON @ 2,000 GPM
7 PSI + 27 PSI = 34 PSI

$\Rightarrow$ HEAD LOSS = 34 × 2.31 = 78.54
ADD SAFETY FACTOR OF 1.5 ~ 120'

$$\Rightarrow \text{HORSEPOWER @ 2,000 GPM} = \frac{(2{,}000)(120)}{(0.75)(3960)}$$

HP ~ 80

PRESSURE DROP @ 1,500 GPM
4 PSI + 16 PSI = 20 PSI

$\Rightarrow$ HEAD LOSS = 20 × 2.31 = 46.2
ADD SAFETY FACTOR OF 1.5 ~ 70'

$$\Rightarrow \text{HORSEPOWER @ 1,500 GPM} = \frac{(1{,}500)(70)}{(0.75)(3960)}$$

HP ~ 35

EFFLUENT PUMPS
PRESSURE DROP = 325'

$\Rightarrow$ @ 2,000 GPM HP = 220

$\Rightarrow$ @ 1,500 GPM HP = 165

PROJECT BAAP FS ELECTRICAL SERVICE REQUIREMENTS IN NEW FACILITY (2,000 GPM MAX FLOW)	COMP. BY JSM	JOB NO. 6853-09
	CHK. BY GNR	DATE 4/19/93

ALTERNATIVE PBG-GW2: IRM & CARBON

2 SOURCE CONTROL WELLS (15 HP EA (NORMAL OP))	= 30 HP } 150 HP
4 BOUNDARY CONTROL WELLS (30 HP EA)	= 120 HP }
1 INFLUENT TRANSFER PUMP (65 HP)	= 65 HP
1 EFFLUENT TRANSFER PUMP (220 HP)	= 220 HP
	435 HP

$435\ HP \times \frac{0.746\ KW}{HP} = 325\ KW$ ✓

ADD ~ 20 KW FOR BUILDING LIGHT & POWER → 345 KW

⇒ 1,000 AMP / 480 V / 3-PHASE & 500 KVA TRANSFORMER IS SUFFICIENT

ALTERNATIVE PBG-GW4: IRM & AIR STRIPPING - CARBON

EXTRACTION WELL PUMPS	= 150 HP
1 INFLUENT TRANSFER PUMP (50 HP)	= 50 HP
1 AIR STRIPPER SUMP PUMP (65 HP)	= 65 HP
3 BLOWERS (7.5 HP EA)	= 22.5 HP
1 EFFLUENT TRANSFER PUMP (220 HP)	= 220 HP
	507.5 HP

$507.5 \times \frac{0.746\ KW}{HP} = 379\ KW$ ✓

ADD: 75 KW FOR THREE AIR STRIPPER EMISSION HEATERS
+ ~ 30 KW FOR BUILDING LIGHT & POWER → 484 KW

⇒ 1,100 AMP / 480 V / 3-PHASE & 500 KVA TRANSFORMER IS SUFFICIENT

ALTERNATIVE PBG-GW5: IRM & RESIN ADSORPTION

EXTRACTION WELL PUMPS	= 150 HP
1 INFLUENT TRANSFER PUMP (350 HP)	= 350 HP
1 EFFLUENT TRANSFER PUMP (220 HP)	= 220 HP
	720 HP

$720\ HP \times \frac{0.746\ KW}{HP} = 537\ KW$ ✓

ADD ~ 16 KW FOR BUILDING LIGHT & POWER → 553 KW

⇒ 1,500 AMP / 480 V / 3-PHASE & 750 KVA TRANSFORMER IS SUFFICIENT

PROJECT BAAP FS ELECTRICAL SERVICE REQUIREMENTS IN NEW FACILITY (2,000 GPM MAX FLOW)	COMP. BY JSM	JOB NO. 6853-09
	CHK. BY [illegible]	DATE 4/19/93

ALTERNATIVE PBG-GW7: IRM & UV REDUCTION – CARBON

EXTRACTION WELL PUMPS	= 150 HP
1 INFLUENT TRANSFER PUMP (80 HP)	= 80 HP
1 EFFLUENT TRANSFER PUMP (220 HP)	= 220 HP
	450 HP

$450 \text{ HP} \times \frac{0.746 \text{ KW}}{\text{HP}} = 336 \text{ KW}$

ADD: 650 KW FOR UV REACTORS
+ ~27 KW FOR BUILDING LIGHT & POWER → 1,013 KW

⇒ 2,100 AMP / 480 V / 3 PHASE & 1,500 KVA TRANSFORMER IS SUFFICIENT

PROJECT BAAP FS MASS CALCS FOR CONTAMINANTS REMOVED FROM GROUNDWATER (ANNUALLY)	COMP. BY JSM CHK. BY MPM	JOB NO. 6853-09 DATE 5/18/93

MASS OF CONTAMINANTS REMOVED FROM BCW WATER:
≈ 50 μg/l TOTAL OF CCL4, CHCL3, TRCLE, 24DNT, 26DNT, AND NNDPA

PUMPING BCWs AT 1,500 GPM:

$1,500 \text{ GPM} \times \frac{3.785\ l}{\text{GAL}} \times \frac{50\ \mu g}{l} \times \frac{60\ \text{MIN}}{\text{HR}} \times \frac{24\ \text{HRS}}{\text{DAY}} \times \frac{365\ \text{DAYS}}{\text{YR}} \times \frac{1\ g}{1\times10^{6}\ \mu g}$

$= 149,205\ g/\text{YR} \times \frac{2.205 \times 10^{-3}}{1\ g}$

$= 328.6\ \text{lbs/YR} \rightarrow \sim \frac{330\ \text{lbs}}{\text{YR}}$ FROM BCWs

MASS OF CONTAMINANTS REMOVED FROM SCW WATER:
≈ 45 μg/l TOTAL OF CONTAMINANTS

PUMPING SCWs AT 500 GPM:

$500\ \text{GPM} \times 3.785 \times 45 \times 60 \times 24 \times 365 \times 1\times10^{-6}$

$= 44,761\ g/\text{YR}$

$= 98.6\ \text{lbs/YR} \rightarrow \sim \frac{100\ \text{lbs}}{\text{YR}}$ FROM SCWs

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ABB Environmental Services, Inc.
110 Free Street
P.O. Box 7050
Portland, Maine 04112-7050
Telephone (207) 775-5400
Fax (207) 772-4762

TELEPHONE MEMORANDUM

PROJECT NO.: 6853-09

DATE: 4/20/93

CLIENT: AEC, BADGER AAP

PROJECT DESCRIPTION: GROUNDWATER REMEDIATION

BETWEEN: JOHN MACKINNON

AND: DENNIS THUROW (OLIN)

SUBJECT: UTILITIES @ IRM

DT STATED THAT THE ELECTRICAL SERVICE TO THE IRM IS 400 A / 480 V / 3 PHASE. IF THERE ARE ADDITIONAL POWER REQUIREMENTS, A 12,470 V 3 PHASE TRANSMISSION LINE PASSES 200 FEET FROM THE IRM FACILITY. CONSUMPTION AT THE IRM IS CURRENTLY 50,000 KWHR PER MONTH. WISCONSIN POWER AND LIGHT CHARGES $0.04/KWHR.

DT STATED THAT WATER IS SUPPLIED FROM A 3/4" COPPER LINE CONNECTED TO A 3" PROCESS (NOT POTABLE) WATER MAIN LOCATED 150 FEET FROM IRM.

DT STATED CALGON CHARGES $10,500 PER TRUCKLOAD FOR REACTIVATED CARBON

DISTRIBUTION:
ABB

APPENDIX D.7

VENDOR INFORMATION: GROUNDWATER ALTERNATIVES

PROPELLANT BURNING GROUND

Specialty Purifications

Rohm and Haas Company
Building 20, Suite 100
727 Norristown Road
Spring House, PA 19477
Phone: 215 641-7099, Fax: 215 283-2875

April 29, 1993

Mr. John MacKinnon
ABB Environmental Services, Inc.
110 Free Street
P. O. Box 7050
Portland, Maine 04112-7050

Dear John:

Thank you for informing us of the modifications to the assumptions for the final design for your groundwater remediation project with USATHAMA. Outlined below are the changes in the model assumptions and our updated comments on the potential use of Ambersorb 563 adsorbent for your application.

Assumption Changes

1. Influent water analysis assumes 0 µg/L methylene chloride and 1 µg/L benzene. All other contaminants are the same as outlined in your telefax dated March 11, 1993.
2. 65 year project life rather than 20 years
3. Electricity cost at $0.04/kW-hr rather than $0.09/kW-hr
4. 5 percent interest rate rather than 7 percent
5. Eight model 10 Calgon GAC adsorbers rather than four adsorbers
6. Off-site regeneration of GAC at costs noted previously

As outlined in my letter to you dated April 5, 1993, the changes in the influent water analysis composition have a significant impact on regeneration frequency and the resulting operating costs. The first component to break through is now chloroform rather than methylene chloride. Outlined below is the estimated **capital investment costs for a 2000 GPM** Ambersorb 563 adsorbent system and a liquid phase GAC system. **The operating costs are calculated based on a flow rate of 1500 GPM.**

Economic Comparison	**Ambersorb 563 Adsorbent**	**GAC**
EPA Estimated Construction Cost for Adsorbers	$0.48 MM	$1.31 MM
Regeneration Equipment (Ambersorb only)	$0.68 MM	
Construction Overhead (50%)	$0.58 MM	$0.65 MM
Cost of Initial Adsorbent Charge	$0.92 MM	$0.12 MM
PV of Replacement Cost of Adsorbent	$0.53 MM	
TOTAL INSTALLED COST	**$3.2 MM**	**$2.1 MM**

Again, please note that the Ambersorb adsorbent system contains only 26,350 pounds of Ambersorb 563 adsorbent (TWO adsorbent vessels) compared against 160,000 pounds of liquid phase GAC (EIGHT adsorbent vessels). The estimated equipment and construction cost for the Ambersorb 563 adsorbent system including the regeneration and prefiltration equipment is slightly lower than the GAC system because of the smaller system size. The total installed cost for the Ambersorb adsorbent system is higher than for GAC because of the initial purchase of Ambersorb 563 adsorbent and subsequent replacements assuming a service life of 20 years for Ambersorb 563 adsorbent. You may still want to consider potential leasing arrangements to lessen the initial capital investment burden ($0.92 MM) for the initial purchase of Ambersorb 563 adsorbent and transfer the cost to an operating cost line item. We can discuss this concept in further detail at your convenience.

Unfortunately, our model can only calculate the net present value replacement cost for Ambersorb 563 adsorbent and does not take into account the replacement cost for the Ambersorb system or GAC equipment. The material of construction for the Ambersorb adsorbent system is 904L. Estimated service life for the equipment is at least 20 years. Estimated costs for the Ambersorb 563 adsorbent vessels, prefilter and steam regeneration equipment are outlined below:

Ambersorb Adsorbent System Equipment List	
Ambersorb 563 Adsorbent Vessels	$0.48 MM
Prefilter system	$0.09 MM
Regeneration Equipment	
Steam Boiler	$0.20 MM
Separator, Condenser & Piping	$0.25 MM
Superloader	$0.14 MM
Total Ambersorb System Equipment	$1.16 MM

Outlined below are the estimated annual operating costs assuming operation at **1500 GPM:**

Annual Operating Cost Comparison	**Ambersorb 563 Adsorbent**	**GAC**
Process and Building Energy Cost	$1.6 M	$0.3 M
Pumping Cost	$41.3 M	$4.8 M
Maintenance Material Cost	$2.4 M	$7.5 M
Operating Labor Cost	$42.4 M	$103.6 M
Total EPA Annual Operating Cost	**$87.7 M**	**$116.3 M**
Additional Regeneration or Rebed Costs	$20.4 M	$319.7 M
TOTAL ANNUAL OPERATING COST	**$108.1 M**	**$436.0 M**

Operation at 2000 GPM will result in an annual increase of $21 M for the Ambersorb 563 adsorbent system (mainly due to pumping costs) and $108 M for the liquid phase GAC system (due to higher rebed costs).

Outlined below are key process parameters assuming operation at **2,000 gpm**:

System Parameters (2000 GPM)	Ambersorb 563 Adsorbent	GAC
Flow Rate Loading (gpm/cu. ft.)	2.7	0.33
Empty Bed Contact Time (minutes)	2.8	22.6
Number of Adsorber Vessels	2	8
Vessel Diameter (feet)	8.5	10.0
Vessel Height (feet)	6.5	9.6
Pounds of Adsorbent per Vessel	12,170	20,000
Pressure Drop Across Each Adsorber (psi)	54	6
Total Pounds Adsorbent in System	26,350	160,000
Number of Regenerations or GAC rebeds/year	7	34

Please note that there are only two Ambersorb adsorbent vessels and they are considerably smaller and operate at significantly higher flow rate loadings than the GAC units. The total pounds of Ambersorb 563 adsorbent includes 2010 pounds of adsorbent for a separate "Superloading" column to treat the aqueous layer from the steam condensate rather than purchasing a large storage tank to reserve the aqueous layer until the next regeneration. We felt this was a better design approach since there will be approximately seven to ten weeks between each regeneration.

Approximately 468 pounds of concentrated organics will be recovered per year operating at 2000 GPM. Approximately 351 pounds of concentrated organics would be recovered per year operating at only 1500 GPM. This stream is typically disposed of as hazardous waste or sent to a cement kiln operation for its fuel value. This is the only "waste stream" that must be handled.

We do not have data confirming whether the 2,4-DNT will condense in the aqueous or organic layer of the steam condensate. IF the 2,4 DNT condenses in the FIRST bed volume of steam as condensate, there is a strong possibility that the 2,4-DNT will reside in the organic layer. We estimate that approximately 3500 grams of 2,4-DNT will be desorbed during each regeneration assuming 100 percent regeneration efficiency.

Unfortunately, the reports that I mentioned to you regarding the comparison of Ambersorb carbonaceous adsorbent to granular activated carbon for the removal of high energy organics from munitions wastewaters (TEGDN, MTN, BDNPA, BDNPF, TNT and RDX) do not mention handling of spent methanol regenerant or safety issues. Attached is a copy of a report entitled "Adsorption of Navy High Energy Ingredients from Water: Comparison of Activated Carbon and Carbonaceous Resin" by John C. Hoffsommer (Naval Surface Weapons Center) for your review.

Per your request, I have also obtained approval from Mr. Larry Lynch to discuss his operational experience with an Ambersorb 563 adsorbent system for the treatment of contaminated groundwater. His telephone number is (206)889-3983.

We hope this information is useful. Please feel free to contact me at (215)641-7478 if you need any further clarification or would like to discuss our design assumptions in more detail.

Thank you for your interest in Ambersorb adsorbent technology for your separation needs.

Sincerely,

Debbie

Deborah A. Plantz
Business Development Manager
Specialty Purifications

DAP/dap
Attachment

Ambersorb® 563 Adsorbent System
Cost and Performance Factors - Assumptions

Life of Project (years)	65	
GAC Initial Charge Cost per pound	$0.775	($15,500/truckload)
GAC Replacement Cost per pound	$0.545	($10,900/truckload)
Ambersorb 563 Adsorbent cost/lb	$35.00	
Electricity Cost ($/kW hr)	$0.04	
Labor Rate ($/hour)	$40.00	
Cost of Steam ($/1000 lb)	$9.28	
Waste Disposal Cost ($/gallon)	$7.27	
Corporate tax rate	38%	
Interest Rate	5%	
Total BVs of steam per regeneration	10	
Lbs. cooling water/lbs. steam	36	
Adsorbent System Efficiency	85%	

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Fax (207) 772-4762

TELEPHONE MEMORANDUM

PROJECT NO.: 6853-09 DATE: 5/13/93
CLIENT: AEC / BAAP
PROJECT DESCRIPTION: GROUNDWATER REMEDIATION
BETWEEN: JOHN MACKINNON
AND: DEB PLANTZ
SUBJECT: RESIN ADSORPTION

DP FOLLOWED UP WITH FOLLOWING INFO:
(1) CONTACT FOR CARBON MODEL:
EPA LEWIS PUBLISHERS
(800) 272-7737
MANUAL & FLOPPY DISC
(2) TREAT STUDY CONTACT
- ROY. F. WESTON
DR. JOHN THOROUGHGOOD
(215) 993-5056
- IT
CHUCK PARMELE
(615) 690-3211
- LARRY LYNCH

(206) 889-3983

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TELEPHONE MEMORANDUM (Cont.)

SHEET 2 OF 2

PROJECT NO. 6853-09 DATE: 5/13/93

SUBJECT: RESIN ADSORPTION

DISCUSSION:

(3) @ 1,500 GPM, 5 REGENERATIONS/YEAR ARE REQUIRED

(4) TYPE OF PREFILTRATION SYSTEM — TECHNICAL SPECIALISTS

304 SS ASME — TWX 2022-3

150 PSIG — 20 BAGS EACH

20 MICRONS — 40" LONG, 45 FT^2 FOOTPRINT

(5) ELECTRICAL REQUIREMENTS → PRIMARILY PUMPING

(6) WATER : 37 lbs COOLING WATER / lb OF STEAM

ABB
ASEA BROWN BOVERI

ABB Environmental Services, Inc.
110 Free Street
P.O. Box 7050
Portland, Maine 04112-7050
Telephone (207) 775-5400
Fax (207) 772-4762

TELEPHONE MEMORANDUM

PROJECT NO.: 6853-09 DATE: 5/18/93
CLIENT: AEC / BADGER AAP
PROJECT DESCRIPTION: GROUNDWATER REMEDIATION
BETWEEN: LARRY LYNCH, VAN WATERS (206) 889-3983
AND: JOHN MACKINNON
SUBJECT: RESIN ADSORPTION PERFORMANCE & TREAT STUDY INFO

LL HAS DONE SOME PILOT-SCALE TREATABILITY STUDIES TO GATHER INFO CONCERNING ROHM & HAAS RESIN ADSORPTION.

LESSONS LEARNED:

- REGENERATION OF RESIN USED IN TREATMENT OF CHLORINATED COMPOUNDS CAN PRODUCE HYDROCHLORIC ACID IF THE REGENERANT IS STEAM. ACID WOULD ACCELERATE SYSTEM CORROSION.
- LL PLANS TO TEST OTHER REGENERANTS (i.e., INERT GAS AND METHANOL)

LL PLANS TO CONSTRUCT 140 GPM PILOT-SCALE SYSTEM AND MODULIZE IT SO THAT IT CAN BE FIT AND SHIPPED IN 20-FOOT STEAMSHIP CONTAINERS. LL ALSO STATED THAT NO FULL-SCALE SYSTEMS HAVE BEEN CONSTRUCTED.

DISTRIBUTION:
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Solarchem

April 22, 1993

Mr. John MacKinnon
ABB Environmental Services, Inc.
110 Free Street
P O Box 7050
Portland, Maine
04112-7050

Dear John:

This letter responds to the information requested in your fax dated April 15th, 1993 with respect to the Badger AAP project.

In reviewing the water chemistry, flow and discharge targets, it appears as if this treatment requirement is ideally suited for a hybrid system consisting of our UV reduction process, **Rayox**®-R, followed by an activated carbon polish step targeted on removing the DNT alone. The delightful advantages of this approach include:

- **Rayox**®-R was specifically developed to target chlorinated alkanes which have traditionally been difficult to oxidize and, like chloroform and 1,2 DCA, are often difficult to adsorb on carbon. The **Rayox**®-R first step in the proposed hybrid process would very efficiently remove everything except the DNT

- DNT loads extremely efficiently on GAC and, in the absence of other competing compounds, the useful life of the carbon should be about 25-30 years

- because **Rayox**®-R is a destruction process and the GAC will last so long, one has a design with essentially ***no*** secondary wastestreams for all practical purposes

- lastly, the carbon system will act as safety backup in the short term in the unlikely event of a glitch in the UV reduction system's operation. This feature will essentially guarantee no off-spec discharge.

All in all, this proposed treatment alternative appears to represent an attractive option taking advantage of the best capabilities of two complementary systems.

Solarchem

In the point form discussion which follows, I have addressed each of the items in your information request (page 3 of your fax) :

1. The **Rayox®**-R portion of the proposed system will consist of 3 parallel trains of one 4 x 30 kW and one 3 x 30 kW standard reactor skids as shown in the appended flow diagram. The GAC portion of the system will consists of two parallel trains of 2 x 20,000 lb canisters each handling 750 GPM. If 2000 GPM flow at maximum concentration is absolutely required, 3 trains at 2 x 20000 lb would be required along with additional UV reactors resulting in a four parallel train UV configuration again as noted in the flow schematic.

2. The UV and GAC systems at 1500 GPM would have the dimensions shown in the attached layout/flow schematic. Again, if larger flows are contemplated, equipment space is directly proportional to flow and can be quickly calculated. A picture of a typical multi-skid installation (in this case 3 x 3 x 30 kW reactors) is show in the appended photograph.

3. Utilities are primarily related to the UV requirement and would involve a load of 650 kW of 480/3/60 power. This load does not include pump power to feed the system either directly from the wells or from an equalization tank because we are unfamiliar with that part of your design configuration. If you are going to size a pump, consider a 5 - 7 lb pressure drop across to the **Rayox®** system.

4. The only auxiliary equipment will be the ENOX 710 additive system to effect the UV reduction process. While this reagent replaces the hydrogen peroxide used in a traditional UV oxidation system, it is presently a patent-applied-for compound. We are prepared to disclose its nature as we have to on a "need-to-know" basis, once mutually acceptable disclosure agreements are in place. For guidance at this point, I can advise that it is an FDA approved food additive so there should be no regulatory problems. A practical storage capacity for this additive would be 5000 gallons which represents a 10 day supply.

5. Operating parameters are as the water comes out of the ground or maybe at a slightly elevated pH (~ 8) . This needs to be confirmed by design testing.

6. There are essentially no secondary wastestreams from the process as discussed above. Indeed, if one goes to three parallel trains of 2 x 20,000 lb GAC vessels for the 1500 GPM design flow, the GAC will ***never*** need to be changed during the 55 year design lifetime of the system. Used UV lamps can be returned to us for recycling.

Solarchem

7. Manpower requirements are nominal. In typical **Rayox**® installations, an operator walks past the equipment once per shift logging appropriate figures. The PLC running the system can also be "asked" to provide a complete printout of system operating conditions. One person for one 8 hour shift once every four months will be required for lamp changes.

8. Flow diagram appended as noted above.

9. A reference for pilot testing of a chlorinated solvents contaminated groundwater treated with **Rayox**®-R is Roger Woeller, a principal of Water and Earth Science Associates in Ottawa, Ontario (telephone 613-839-3053). A system using **Rayox**®-R will soon be started up at Kennedy Space Center for NASA. A contact there is Dan Tierney (telephone 407-861-2027).

10. The estimated capital cost for the **Rayox**®-R/GAC 1500 GPM (2000 GPM) system is \$1.2 million (\$1.6 million) including instrumentation, telemetry, reagent storage/addition requirements as well as the initial charge of carbon and the present value of the mid project changeout (\$20,000). No allowance has been made for pumps, equalization tanks or buildings.

11. O&M costs including power, (based on your latest cost figure of \$0.04/kWh) lamp replacement, additives and people time/parts are estimated at \$0.81/1000 gallons in the ratio 37:24:34:5

12 The present value of the initial capital and O & M costs over 65 years at a discount rate of 5 percent is \$~~17.7~~ million for the 1500 GPM case and \$~~23.6~~ million for the 2000 GPM case. 12.8 PER D. NOLAN 4/23/93 17.1

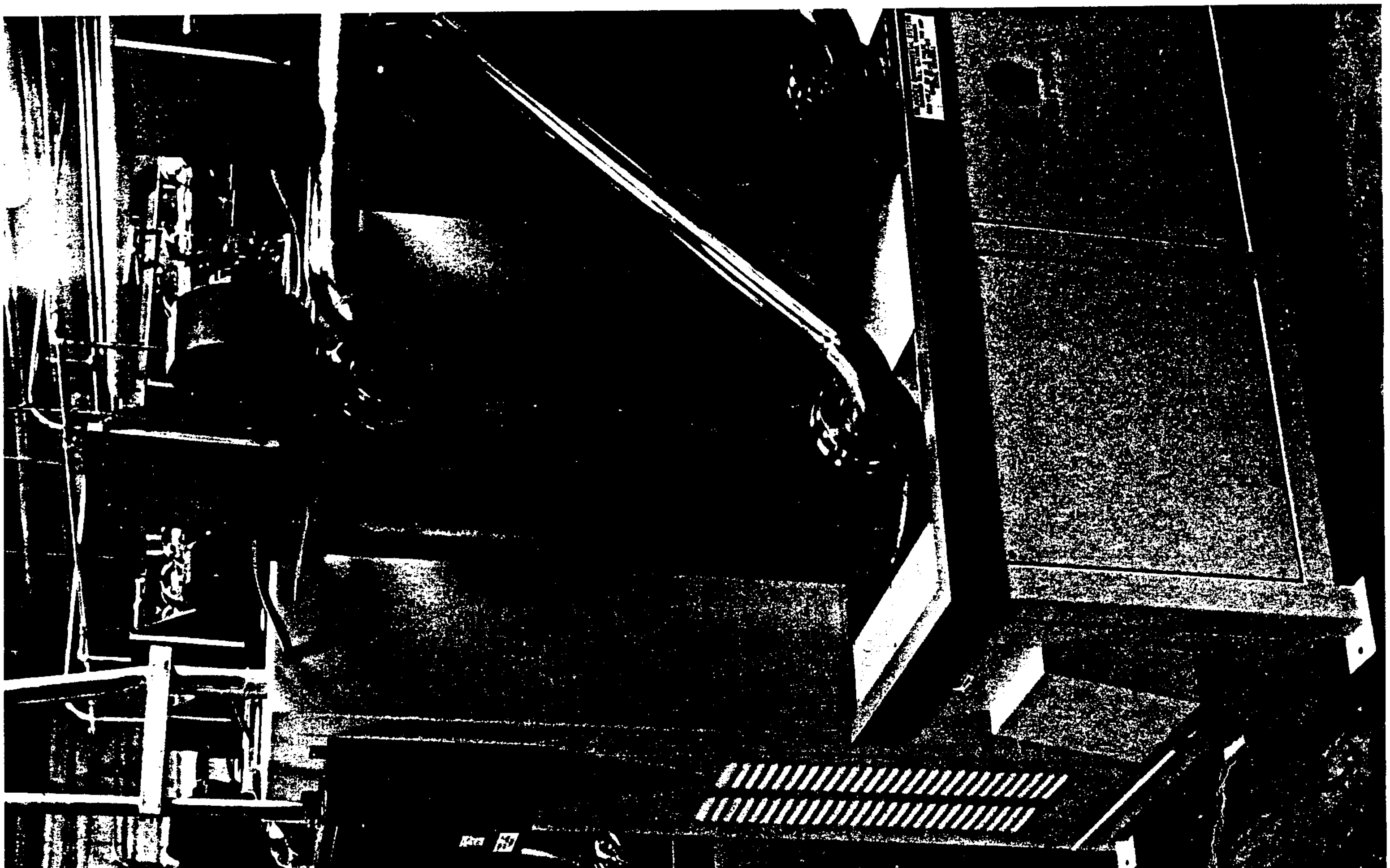
Please call if further clarification would be helpful.

Yours truly,

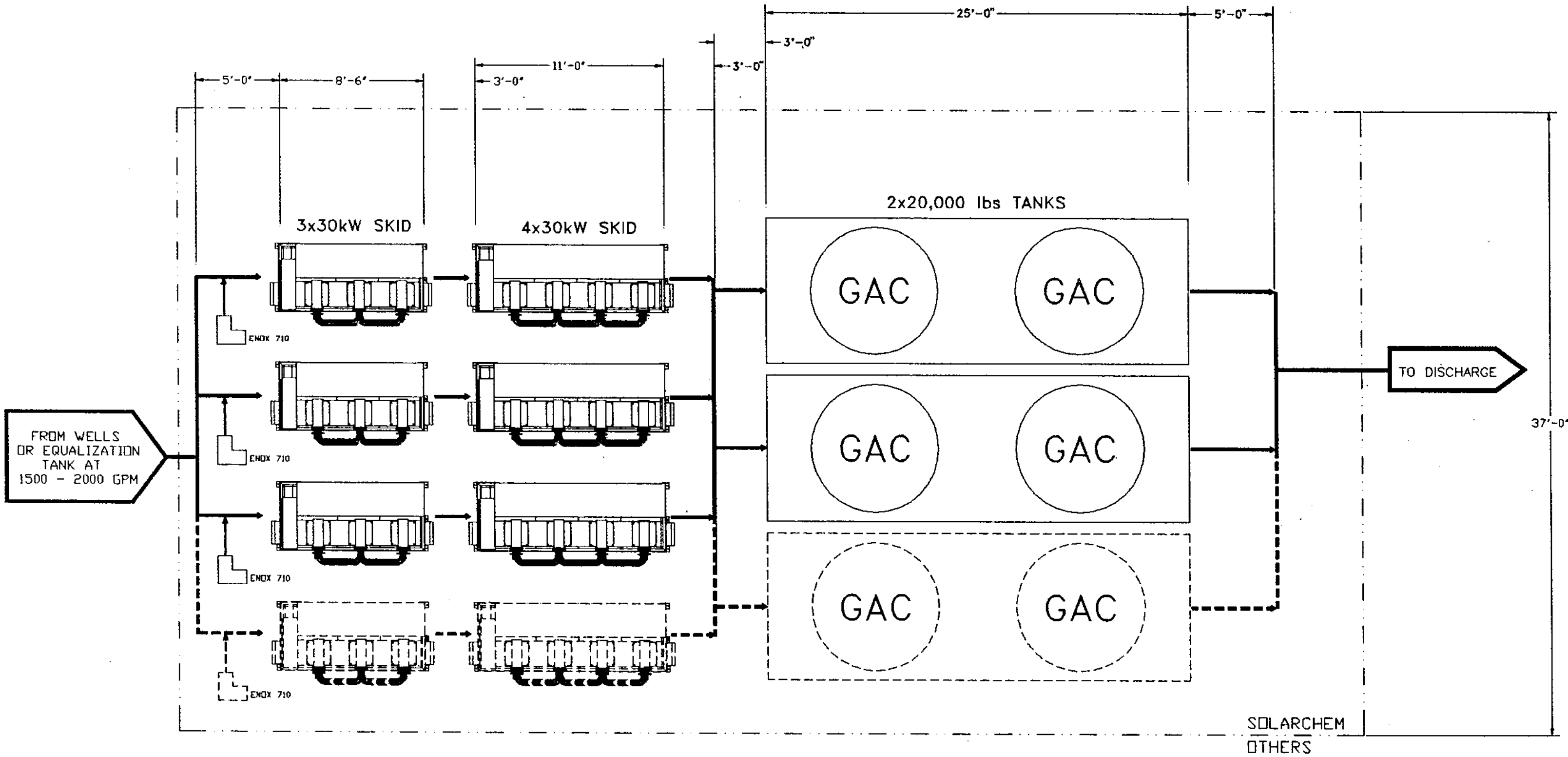
SOLARCHEM ENVIRONMENTAL SYSTEMS
per:

P. Daniel Nolan
Vice President, Sales

PWS/ps
60.A.03



FLOW SCHEMATIC RAYOX-R/GAC SYSTEM FOR BADGER AAP



NOTES:
1. DOTTED LINE ADDITION SHOWS REQUIREMENT FOR 2000 GPM FLOW
2. SKID DIMENSIONS FOR RAYOX ARE 3'x8'x12'H AND 3'x11'x12'H . (HEIGHT ALLOWS FOR LAMP CHANGE CLEARANCE)
3. SKID DIMENSIONS FOR GAC ARE 12'x25'x18'H
4. OVERALL DIMENSIONS FOR A 2000 GPM SYSTEM ARE APPROXIMATELY 65'x40' AND PROPORTIONATELY LESS FOR 1500 GPM SYSTEM.

REVISIONS

REV	DESCRIPTION	DATE	APPV'D
A			
B			
C			
D			
E			

NOTES

FINISH

MATERIAL

DIMENSIONS IN INCHES (unless otherwise specified)

TOLERANCES (unless otherwise specified)

ANGULAR	±0°30'	DECIMAL 2 PLACES	±.010
FRACTIONAL	±1/32	DECIMAL 3 PLACES	±.005
DECIMAL 1 PLACE	±.015	DECIMAL 4 PLACES	±.0005

Solarchem
7320 SMOKE RANCH RD. LAS VEGAS, NEVADA U.S.A. 89128
130 ROYAL CREST CT. MARKHAM, ONTARIO CANADA L3R 0A1

	NAME	SIGN.	DATE
DRAFT.	JKMB		20 APR/93
DESIGN.	P.S.		19 APR/93
CHECK			
APPR.			

TITLE FLOW SCHEMATIC RAYOX-R/GAC SYSTEM FOR BADGER AAP

SHEET No. SHEET 1 OF 1 — SCALE NONE

DWG. No. 000-RD-900030 — REV. 2

000-RD-900030

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Telephone (207) 775-5400
Fax (207) 772-4762

TELEPHONE MEMORANDUM

PROJECT NO.: 6853-09
DATE: 5/13/93
CLIENT: AEC / BAAP
PROJECT DESCRIPTION: GROUNDWATER REMEDIATION
BETWEEN: JOHN MACKINNON
AND: DAN NOLEN - SOLARCHEM
SUBJECT: TREAT STUDY COSTS, LIFE EXPECTANCY OF EQUIPMENT, O & M

(1) $3,000 - $5,000 FOR TREAT STUDY. REQUIRES ONE 55 GALLON DRUM OF WATER SENT TO SOLARCHEM FACILITY. FOUR OR FIVE TESTS ARE RUN USING DIFFERENT DOSES OF REAGENTS. RESULTS ARE # OF REACTORS REQUIRED FOR SYSTEM AND COST / 1,000 GALLONS.

(2) UV EQUIPMENT IS 316 SS. COULD ASSUME 20-25 YEAR LIFE EXPECTANCY.

(3) AIR-OPERATED WIPER. TRAINING REQUIRED FOR MAINTENANCE. LAMP CHANGE EVERY 4 MONTHS.

DISTRIBUTION:
ABB
FILE

Delta Cooling Towers, Inc.
134 Clinton Road
P. O. Box 952
Fairfield, New Jersey 07004-2970
Telephone 201/227-0300
Fax 201/227-0458

Delta Cooling Towers

May 3, 1993

John MacKinnon
ABB Environmental Services, Inc
110 Free Street
P.O. Box 7050
Portland, Maine 04112-7050
(207) 772-4762

Re: Army Environmental Center, Badger AAP

Dear John,

Delta Cooling Towers, Inc. is pleased to quote for your application, (3) model ΔS6-160R **Vanguard®** air strippers.

This quotation is for (3) air strippers in parallel to treat 2000 gpm contaminated water. Each air stripper will allow for 667 gpm each, with 2675 scfm vapor throughput each. Please refer to the quote form attached. Vapor phase carbon off gas treatment system is quoted as a separate item.

Thank you for considering Delta Cooling Towers, Inc. equipment, we look forward to working with you on future projects.

Sincerely,

Keith Kay
Sales Engineer

QUOTATION NO: ________

Delta Cooling Towers, Inc.

P.O. Box 952
Fairfield, New Jersey 07004-2970
PHONE: 201/227-0300
FAX: 201/227-0458

VANGUARD® AIR STRIPPER

Item	Component Description	Incl'd	Qty.	Not Incl'd	Remarks
19.	PREMOUNTING & PREWIRING OF CONTROL PANEL.	☐		☒	
20.	TELEMETRY REMOTE TERMINAL SYSTEM.	☐		☒	
21.	CHEMICAL CLEANING SYSTEM.	☐		☒	
22.	IRON REMOVAL SYSTEM.	☐		☒	
23.	SOIL VENTING SYSTEM.	☐		☒	
24.	CARBON ABSORPTION SYSTEMS. A. VAPOR PHASE - IF REQ'D ADD $78,000.	☐	3	☒	25 KW X-PROOF HEATER PLUS 3200# CARBON IN 2 UNITS PER EACH AIRSTRIPPER
	B. LIQUID PHASE $10,400	☐		☒	
	ADDITIONAL ITEMS. 25KW HEATER PER K. KAY 5/13				
25.		☐		☐	
26.		☐		☐	
27.		☐		☐	

TOTAL MATERIAL COST IS $ 156,000.

THIS QUOTATION IS ☐ FIRM for 30 days and is subject to review thereafter.

THIS QUOTATION IS ☒ FOR BUDGET PURPOSES ONLY.

Price quoted is F.O.B. Fairfield, N.J. and is based on shipment within 90 days after receipt of formal purchase order. Shipment can be made approximately 6-8 weeks after receipt of purchase order, or approval of drawings, if applicable. Terms of payment are net 30 days after date of invoice.

We trust this proposal is complete and satisfies your request. X-PROOF AIR HEATER LEAD TIME MAY NOT BE 6-8 WKS.
If we can be of further assistance, please do not hesitate to contact us.

Very truly yours,
KEITH KAY
Delta Cooling Towers, Inc.

This quotation is submitted on behalf of Delta Cooling Towers, Inc. and is subject to formal review prior to acceptance. All attachments including the standard Conditions of Sale and Warranty, constitute our complete proposal.

Represented by:
(Company) ________
(Address) ________
(City, State, Zip) ________
(Telephone No.) ________
(Signature) ________

enc. ☐ — List Attached.
cc: ☐ — Delta, Fairfield.

MANUFACTURER OF NON-CORROSIVE COOLING TOWERS, AIR STRIPPERS AND TANKS

DATE	SYM	DR	REVISION RECORD	AUTH	CK
8/8/92	A	KMK	DRAWING NUMBER ADDED	[illegible]	
1/25/93	B	KMK	FEED PUMP, [illegible], ADDED	CNK	
[illegible]/92	C	KMK	REVISED FOR 8/92 RELEASE	CNK	

(1) DELTA VANGUARD® AIR STRIPPERS
1'0" – 5'0" IN 6 INCH INCREMENTS
5'0" – 10'0" IN 1 FOOT INCREMENTS
SHELL MATERIAL F.R.P., S/S OR ALUMINUM

PACKING
DELTA-PAK® (STRUCTURED) OR RANDOM/DUMPED

(2) SKID MOUNTING; STEEL PLATFORM COATED WITH CORROSION RESISTANT BLACK PAINT

(4) ACCESS LADDER & SAFETY CAGE, MATERIAL: ALUMINUM OR FIBERGLASS, WITH NON-SKID RUNGS, MEETS OR EXCEEDS OSHA STANDARDS.

(7) VIBRATION CUT OUT SWITCH PROTECTS BLOWER FROM EXCESSIVE VIBRATION.

(10B) BLOWER AIR PREHEATER FOR SEVERE WINTER OPERATION

(11) TRANSFER PUMP PACKAGE MOUNTING & PIPING AVAILABLE WITH SKID ONLY

(15) TANKS; 200–2000 GALLON CAPACITY, MATERIAL: MDPE COVERS & FITTINGS AVAILABLE

(16) WELL PUMPS; STAINLESS STEEL, TEFLON SEALS ELECTRIC OR PNEUMATIC

(17) WELL LIQUID LEVEL CONTROL, INTRINSICALLY SAFE

(18) CONTROL PANEL
NEMA 4 – STD.
NEMA 7,12 – OPT.

(20) TELEMETRY REMOTE TERMINAL ALARM/STATUS/RELAYS SOFTWARE

(21) CHEMICAL CLEANING SYSTEM
5–150 GPM, 1–5 HP.,
SKID MOUNTED, PREWIRED, PREPIPED, CHEMICALLY RESISTANT PUMP & MOTOR, MIXING CHAMBER, HOSE, VALVES, GAUGES, pH CONTROLLER AND STARTER
ADDITIONAL HOSE – OPTIONAL

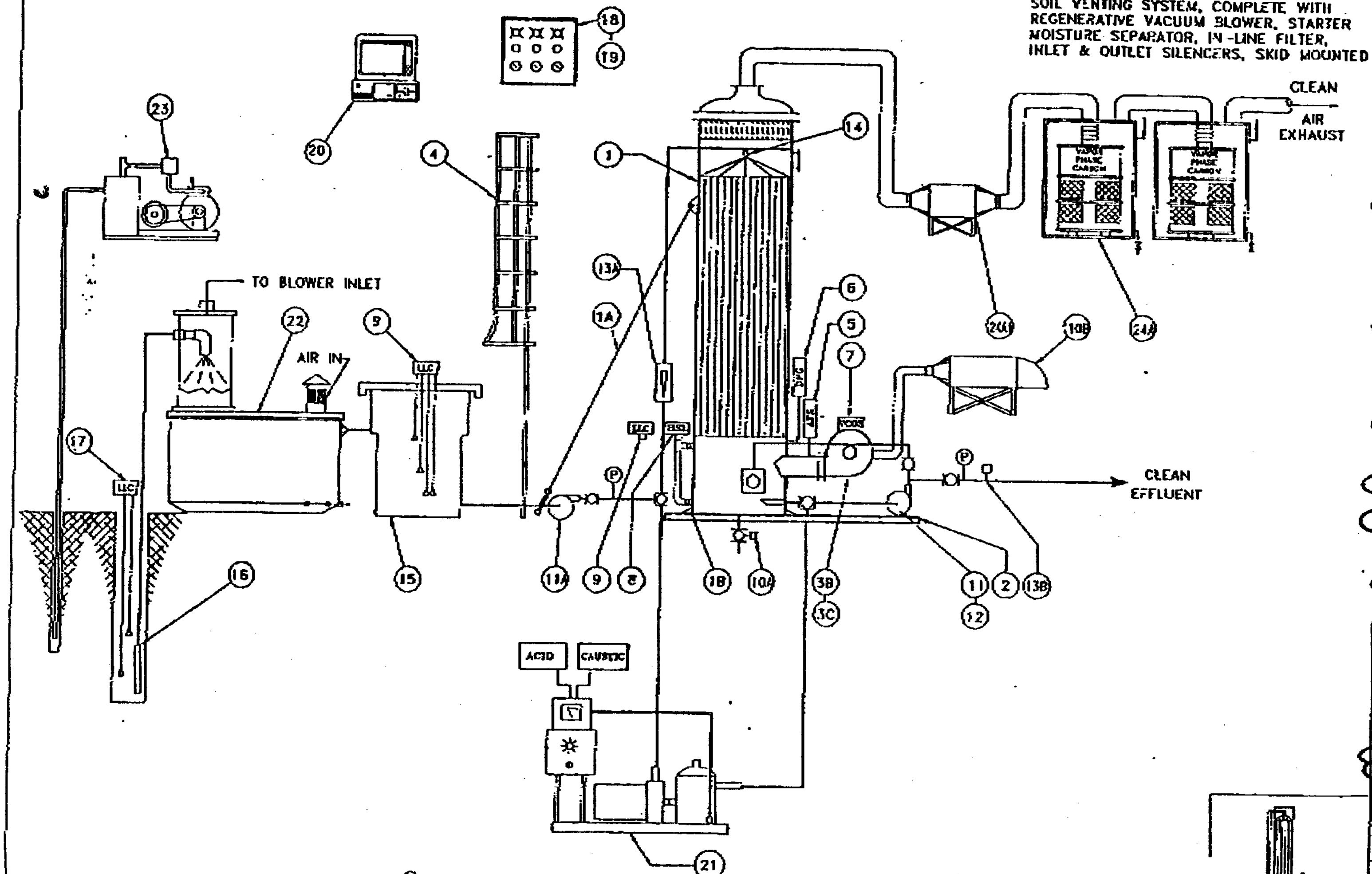
(22) IRON REMOVAL SYSTEM, AERATES FEEDWATER FOR MAXIMUM IRON AND SOLIDS REMOVAL.

(23) SOIL VENTING SYSTEM, COMPLETE WITH REGENERATIVE VACUUM BLOWER, STARTER MOISTURE SEPARATOR, IN-LINE FILTER, INLET & OUTLET SILENCERS, SKID MOUNTED

(24A) VAPOR PHASE CARBON ADSORPTION SYSTEMS SINGLE CANNISTERS AVAILABLE FOR 50–5000 SCFM DUCT WORK AVAIL.

(24A) EXPLOSION PROOF AIR HEATER, AVAIL. IN ELECTRIC NATURAL GAS, OIL AND STEAM.

(24B) LIQUID PHASE CARBON ADSORPTION SYSTEMS SINGLE CANISTERS AVAILABLE FOR 5–200 GPM PRESSURE RELIEF VALVE INCLUDED (NOT SHOWN)



ITEM	BILL OF MATERIALS DESCRIPTION
1	VANGUARD® AIR STRIPPER
1A	GUY WIRE PACKAGE
1B	FREE STANDING DESIGN
2	SKID MOUNTING
3	BLOWER COATING OPTIONS
3A	STANDARD
3B	MASTIC COATING
3C	PREMIUM CORROSION PROTECTION
4	LADDER & CAGE
5	AIR FLOW SWITCH
6A	DIFFERENTIAL PRESSURE GAUGE
6B	DIFFERENTIAL PRESSURE SWITCH GAUGE
7	VIBRATION CUT OUT SWITCH
8	HIGH SUMP LEVEL SWITCH
9	LIQUID LEVEL CONTROL PACKAGE
10	ANTI FREEZE OPTIONS
10A	DRAIN VALVE ACTUATOR
10B	BLOWER AIR PREHEATER
11	TRANSFER PUMP PACKAGE
11A	FEED PUMP
12	PREMOUNTING OF TRANSFER PUMP
13	FLOWMETER TYPES
13A	ROTOMETER/FLOWMETER
13B	FLOWMETER/TOTALIZER
14	DISTRIBUTION NOZZLE(S)
15	STORAGE TANK
16	WELL PUMP
17	WELL LIQUID LEVEL CONTROLS
18	CONTROL PANEL
19	PREMOUNT & PREWIRE OF C.P.
20	REMOTE TELEMETRY TERMINAL SYSTEM
21	CHEMICAL CLEANING SYSTEM
22	IRON REMOVAL SYSTEM
23	SOIL VENTING SYSTEM
24	CARBON ADSORPTION SYSTEM
24A	VAPOR PHASE CARBON
24A1	EXPLOSION PROOF AIR HEATER
24B	LIQUID PHASE CARBON – NOT SHOWN

DELTA COOLING TOWERS, INC.
114 CLINTON RD. FAIRFIELD, NJ. 07004
PH (201) 227-0300 FAX (201) 227-0458

TITLE: VANGUARD® AIR STRIPPER SYSTEM SCHEMATIC
P&ID FOR AIR STRIPPER OPTIONS
DWN BY K.C.W. [illegible]
APPVD BY

VANGUARD® AIR STRIPPER OPTIONS

ABB
ASEA BROWN BOVERI

ABB Environmental Services, Inc.
110 Free Street
P.O. Box 7050
Portland, Maine 04112-7050
Telephone (207) 775-5400
Fax (207) 772-4762

TELEPHONE MEMORANDUM

PROJECT NO.: 6853-09
DATE: 5/13
CLIENT: AEC / BAAP
PROJECT DESCRIPTION: GROUNDWATER REMEDIATION
BETWEEN: JOHN MACKINNON
AND: KEITH KAY
SUBJECT: AIR STRIPPER EQUIPMENT

KK STATED THAT FOR A 3-TOWER SCENARIO:

- DIAMETER = 6'
- OVERALL HEIGHT = 26' - 30'
- PACKING DEPTH = 16'
- 3 1/2" TRIPACK
- 8' x 8' FOR SKID FOOTPRINT
- 7.5 HP BLOWERS
- 7 PSI REQUIRED AT NOZZLES

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1478-49
Form 4/6/90

ABB
ASEA BROWN BOVERI

ABB Environmental Services, Inc.
110 Free Street
P.O. Box 7050
Portland, Maine 04112-7050
Telephone (207) 775-5400
Fax (207) 772-4762

TELEPHONE MEMORANDUM

PROJECT NO.: 6853-09 DATE: 5/13/93
CLIENT: AEC / BAAP
PROJECT DESCRIPTION: GROUNDWATER REMEDIATION
BETWEEN: JOHN MACKINNON
AND: KEITH KAY — DELTA TOWERS
SUBJECT: BLOWERS / HEATERS FOR TOWERS

TOWER SIZE / CAPACITY IS LIMITED BY HEATER RATING. MAX HEATER IS RATED 25 KW => FLOW (2000 GPM) WOULD BE BROKEN INTO THREE STREAMS (1 STREAM PER TOWER). INCREASING TOWER SIZE SO THAT ONLY TWO STREAMS (TWO TOWERS) ARE REQUIRED WOULD NECESSITATE USING HEATERS FUELED WITH OIL OR NATURAL GAS. IF TWO TOWERS USED, EACH TOWER WOULD BE 8 FEET IN DIAMETER WITH 14-15 FEET OF PACKING AND EQUIPPED WITH 10 HP BLOWERS.

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1478-49 Form 4/6/90

DATE: APRIL 23, 1993
PREPARED FOR: JOHN MacKINNON
AFFILIATION: ABB ENVIRONMENTAL
PROJECT LOCATION: BAAP, WI.

ENVIRONMENTAL DRILLING COST ESTIMATE

	DESCRIPTION	UNIT	UNIT COST	EST. QTY.	TOTAL
1.	MOBILIZE DRILL RIG, MATERIALS, DECON EQUIPMENT, SUPPORT TRUCK, TOOLS AND CREW.	L.S.	3500	1	$ 3,500
2.	MUD ROTARY DRILL NOMINAL 18" BOREHOLE.	PER FT.	75	1080	81,000
3.	INSTALL 12" STAINLESS STEEL WELLS.	PER HR.	275	48	13,200
4.	MOVING BETWEEN SITES AND DECONTAMINATION.	PER HR.	275	20	5,500
5.	STANDBY TIME.	PER HR.	275	0	0
6.	PROVIDE DECON EQUIPMENT.	PER DAY	100	30	3,000
7.	PER DIEM. (3-MEN)	PER DAY	165	30	4,950
8.	FURNISH MATERIAL:				
	10" .02 SLOT S.S. SCREEN	PER FT.	100	430	43,000
	10" 304 SCH.10 S.S. RISER	PER FT.	80	650	52,000
	FILTER PACK SAND (100 LB)	PER BAG	15	425	6,375
	BENTONITE CHIPS/POWDER/GRANULES	PER BAG	12	500	6,000
	4-MIL POLY SHEETING	PER ROLL	45	2	90
		ESTIMATED TOTAL			$ 218,615

lnl/rehlabl/ands.rw

Layne

ABB
ASEA BROWN BOVERI

ABB Environmental Services, Inc.
110 Free Street
P.O. Box 7050
Portland, Maine 04112-7050
Telephone (207) 775-5400
Fax (207) 772-4762

TELEPHONE MEMORANDUM

PROJECT NO.: 6853-09 DATE: 4/30/93

CLIENT: AEC, BADGER AAP

PROJECT DESCRIPTION: GROUNDWATER REMEDIATION

BETWEEN: JOHN MACKINNON

AND: DAVE ROGERS

SUBJECT: CARBON ADSORPTION ALTERNATIVE

ASSUMING VIRGIN CARBON

OPERATING THE IRM AT 500 GPM:

- 4 - 6 CHANGE-OUTS PER YEAR

OPERATING THE NEW FACILITY AT 1,500 GPM:

- 10-12 CHANGE-OUTS PER YEAR
- 2 "UNITS"; EACH UNIT IS 2-MODEL 12s IN SERIES
- \$190 - \$275,000 PER UNIT

PRESSURE DROP ACROSS SYSTEM @ 2,000 GPM = 20 PSI

NOTE: VIRGIN CARBON CHARGE = \$15,500 / 20,000 lbs
TRUCKLOAD

DISTRIBUTION:
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ASEA BROWN BOVERI

ABB Environmental Services, Inc.
110 Free Street
P.O. Box 7050
Portland, Maine 04112-7050
Telephone (207) 775-5400
Fax (207) 772-4762

TELEPHONE MEMORANDUM

PROJECT NO.: 6853-09
DATE: 5/13/92
CLIENT: AEC / BAAP
PROJECT DESCRIPTION: GROUNDWATER REMEDIATION
BETWEEN: JOHN MACKINNON
AND: CALGON CORP.
SUBJECT: VAPOR-PHASE CARBON COSTS

VAPOR-PAK 10s, USED IN THE AIR STRIPPING - CARBON ALTERNATIVE, WOULD BE LEASED FROM CALGON. THE LEASING COST FOR EACH VAPOR-PAK 10 IS AS FOLLOWS:

1ST MONTH → $26,000
EACH ADDITIONAL MONTH → $2,300/MONTH

VAPOR-PAK 10 CAPACITY IS 12,500 lbs OF CARBON.

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1478-49 Form 4/6/90

ABB
ASEA BROWN BOVERI

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110 Free Street
P.O. Box 7050
Portland, Maine 04112-7050
Telephone (207) 775-5400
Fax (207) 772-4762

TELEPHONE MEMORANDUM

PROJECT NO.: 6853-09 DATE: 5/13/92
CLIENT: AEC/BAAP
PROJECT DESCRIPTION: GROUNDWATER REMEDIATION
BETWEEN: JOHN MACKINNON
AND: DAVE ROGERS (CALGON)
SUBJECT: UV - REDUCTION / CARBON ALTERNATIVE

DR STATED THAT, GIVEN THE IRM INFLUENT CONCENTRATIONS OF 11/92, THE CARBON USAGE RATE FOR DNTS ALONE IS 1,200 lbs/YEAR.

NOTE: CARBON REBEDS WOULD OCCUR $\frac{60{,}000 \text{ lbs}}{} \times \frac{1 \text{ YEAR}}{1{,}200 \text{ lbs}}$

= EVERY 50 YEARS FOR UV REDUCTION - CARBON ALTERNATIVE

DISTRIBUTION:
ABB
FILE

1478-49 Form 4/6/90

Blake

BLAKE EQUIPMENT COMPANY, INC. P.O. Box 336, Rt 202, Winthrop, ME 04364 207-377-2216
1-800-452-4622

May 12, 1993

ABB Environmental Services, Inc.
110 Free Street
PO Box 7050
Portland, ME 04112-7050

ATTN: John MacKinnon

Dear John:

We are pleased to offer the following budget pricing:

50 HP Submersible Pump System, 155'pump setting:

1 375S500-8DS Grundfos 50 HP submersible pump with 50 HP, 575v. Franklin motor	$ 8,400.00
147' 4" x 21' galvanized pipe T&C	$ 1,617.00
155' 4-0 submersible wire with ground	$ 2,450.00
1 PS1214WBWE04T6 Baker Monitor pitless unit for 12' well casing, 8' bury	$ 5,080.00
TOTAL BUDGET PRICE PER SUBMERSIBLE SYSTEM	$17,547.00

1 Automated Control Systems simplex control panel including: 1 Starter/breaker unit, 50 HP 1 Magnatek Model GPD 503 variable frequency drive 1 Princo conductance probe	$25,000.00
TOTAL BUDGET PRICE PER 50 HP CONTROL PANEL	$25,000.00

40 HP Submersible Pump System, 150'pump setting:

1 375S400-6DS Grundfos 40 HP submersible pump with 40 HP, 575v., Franklin motor	$ 6,210.00
147' 4" x 21' galvanized pipe T&C	$ 1,617.00
155' 4-0 submersible wire with ground	$ 2,450.00
1 PS1214WBWE04T6 Baker Monitor pitless unit for 12' well casing, 8' bury	$ 5,080.00
TOTAL BUDGET PRICE PER SUBMERSIBLE SYSTEM	$15,357.00
1 Automated Control Systems simplex control panel including: 1 Starter/Breaker unit, 40 HP 1 Subtrol pump controller 1 H-O-A switch	$ 5,000.00
TOTAL BUDGET PRICE PER 40 HP CONTROL PANEL	$ 5,000.00

The closer you can get the source of electric power to the well, the less the wire cost will be. A budget price for the wire to deliver power one mile to one well is $15 per foot.

I hope this is the information you need. Please call if you have any questions.

Yours truly,

Gene Weeks

APPENDIX E

DETERRENT BURNING GROUND

APPENDIX E.1

COSTS

DETERRENT BURNING GROUND

DATE: 02-Aug-94 UNIT COST ESTIMATING WORKSHEET

AGRPAGE30 FEASIBILITY STUDY JOB # 6853-09
OPTION SB-1 MINIMAL ACTION
LOCATION: DETERRENT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SB-1 MINIMAL ACTION
COST SUMMARY TABLE

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
DIRECT COST OF OPTION SB-1 MINIMAL ACTION				
INSTITUTIONAL CONTROLS				$10,000
TOTAL DIRECT COST OF OPTION SB-1 MINIMAL ACTION				$10,000
INDIRECT COST OF OPTION SB-1 MINIMAL ACTION				
HEALTH AND SAFETY			0.00%	$0
LEGAL, ADMIN, PERMITTING			0.00%	0
ENGINEERING			0.00%	0
SERVICES DURING CONSTRUCTION			0.00%	0
TOTAL INDIRECT COST OF OPTION SB-1 MINIMAL ACTION				$0
TOTAL CAPITAL (DIRECT + INDIRECT) COST				$10,000
OPERATING AND MAINTENANCE COSTS				
TOTAL ANNUAL OPERATING AND MAINTENANCE COSTS				$7,000
TOTAL PRESENT WORTH OF ANNUAL O&M COSTS (5% FOR THIRTY YEARS)				$108,000
TOTAL PRESENT WORTH OF OPERATING AND MAINTENANCE COSTS				$108,000
TOTAL COST OF OPTION SB-1 MINIMAL ACTION				$118,000

DATE: 02-Aug-94 UNIT COST ESTIMATING WORKSHEET

AGRPAGE30 FEASIBILITY STUDY JOB # 6853-09
OPTION SB-1 MINIMAL ACTION
LOCATION: DETERRENT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SB-1 MINIMAL ACTION

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
INSTITUTIONAL CONTROLS	1	LS	10000.00	$10,000
ANNUAL OPERATING & MAINTENANCE COSTS				
EDUCATIONAL PROGRAMS	1	LS	5000.00	$5,000
FIVE YEAR SITE REVIEW @ $10,000 EVERY FIVE YEARS	1	LS	1809.75	1,810
CONTINGENCY ~10%				190
TOTAL ANNUAL OPERATING & MAINTENANCE COSTS				$7,000

DATE: 02-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION SB-2 CAPPING

JOB # 6853-09

LOCATION: DETERRANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT

ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SB-2 CAPPING COST SUMMARY TABLE DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
DIRECT COST OF OPTION SB-2 CAPPING				
SITE PREPARATION AND MOB/DEMOB				$157,000
CONTAMINATED SOIL DELINEATION				80,000
CAP CONSTRUCTION				163,000
INSTITUTIONAL CONTROLS				10,000
TOTAL DIRECT COST OF OPTION SB-2 CAPPING				$410,000
INDIRECT COST OF OPTION SB-2 CAPPING				
HEALTH AND SAFETY			5.00%	$21,000
LEGAL, ADMIN, PERMITTING			5.00%	21,000
ENGINEERING			10.00%	41,000
SERVICES DURING CONSTRUCTION			10.00%	41,000
TOTAL INDIRECT COST OF OPTION SB-2 CAPPING				$124,000
TOTAL CAPITAL (DIRECT + INDIRECT) COST				$534,000
OPERATING AND MAINTENANCE COSTS				
TOTAL ANNUAL OPERATING AND MAINTENANCE COSTS				$7,000
TOTAL PRESENT WORTH OF O&M COSTS (5% FOR THIRTY YEARS)				$108,000
TOTAL COST OF OPTION SB-2 CAPPING				$642,000

DATE:02-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SB-2 CAPPING
LOCATION: DETERRANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SB-2 CAPPING SITE PREPARATION AND MOB/DEMOB DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
EQUIPMENT (IN OR OUT)				
FRONT END LOADER	2	EA	520.00	$1,040
DUMP TRUCKS	2	EA	260.00	520
DOZER	2	EA	520.00	1,040
OFFICE TRAILER	2	MON	155.00	310
STORAGE TRAILER (2 EA)	4	MON	155.00	620
TRAILER SET-UP & DELIVERY, REMOVAL	3	EA	310.00	930
TOILET (2 EA*2 MON/EA*4.2 WK/MON)	16	WK	25.00	400
WATER CLR (2EA*2MON/EA*4.2WK/MON)	16	WK	25.00	400
WATER (16 WK * 5 DAY/WK)	80	DAY	15.00	1,200
TELEPHONE SERVICE	2	MON	520.00	1,040
ELECTRICAL HOOK-UP	1	LS	2500.00	2,500
ELECTRICAL POWER	2	MON	300.00	600
PICK-UP (2 EA * 2 MON/EA)	4	MON	1035.00	4,140
OFFICE EQUIPMENT	2	MON	1035.00	2,070
PUMPS, TOOLS MINOR EQUIPMENT	1	LS	5000.00	5,000
CLEAR AND GRUB STUMPS - LIGHT TREES	1	AC	3825.00	3,825
STAGING & PARKING - 2 AREAS OF 1/4 AC PER EACH				
12" GRAVEL	2420	SY	6.50	15,730
SOIL STOCKPILE AREAS, 2 AREAS OF 1 AC PER EACH				
CLEAR AND GRUB STUMPS - LIGHT TREE	2	AC	3825.00	7,650
GRADE	3220	CY	2.00	6,440
EARTH BERM - FROM ON-SITE SOIL	480	CY	2.00	960
TOTAL THIS PAGE				$56,415

DATE:02-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION SB-2 CAPPING
JOB # 6853-09

LOCATION: DETERRANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT

ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SB-2 CAPPING SITE PREPARATION AND MOB/DEMOB DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
TOTAL PAGE 2				$56,415
LABORER (2 MEN*10 DAY/MAN*8 HR/DAY)	160	MNHR	30.50	4,880
CARPENTER (2 MEN*10 DAY/MAN*8 HR/DAY)	160	MNHR	39.00	6,240
ELECTRICIAN (2 MEN*10 DAY/MAN*8 HR/DAY	160	MNHR	42.50	6,800
SITE SUPERINTENDANT (2 MON*210 HR/MON)	420	MNHR	62.25	26,145
FOREMAN (2 MON * 210 HR/MON)	420	MNHR	51.75	21,735
CLERK/TYPIST (2 MON * 168 HR/MON)	336	MNHR	26.00	8,736
UNDEVELOPED DESIGN DETAILS ~20%				26,049
TOTAL SITE PREPARATION AND MOB/DEMOB				$157,000

DATE:02-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION SB-2 CAPPING
JOB # 6853-09
LOCATION: DETERRANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SB-2 CAPPING

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
CONTAMINATED SOIL DELINEATION				
DRILLING COSTS	12	BRG	770.00	$9,240
SAMPLE COLLECTION	80	HR	56.00	4,480
ON-SITE ANALYSIS, 2 MEN & EQUIP	5	DAY	4575.00	22,875
OFF-SITE ANALYSIS	50	SMPL	600.00	30,000
UNDEVELOPED DESIGN DETAILS ~20%				13,405
TOTAL CONTAMINATED SOIL DELINEATION				$80,000
INSTITUTIONAL CONTROLS	1	LS	10000.00	$10,000

DATE: 02-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SB-2 CAPPING
LOCATION: DETERRANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SB-2 CAPPING CAP CONSTRUCTION DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
CAP CONSTRUCTION				
CLAY - DELIVERED	3225	CY	8.00	$25,800
SPREAD & COMPACT CLAY	3225	CY	4.00	12,900
60 MIL VLDPE	4850	SY	8.00	38,800
DRAINAGE SAND	1600	CY	8.00	12,800
FILTER FABRIC	500	SY	4.00	2,000
COMMON BORROW	3225	CY	4.00	12,900
TOP SOIL	1600	CY	10.00	16,000
SPREAD & COMPACT SAND, COMMON BORROW, TOP SOIL	6425	CY	2.00	12,850
SEED, FERTILIZE, MULCH	1	AC	2000.00	2,000
UNDEVELOPED DESIGN DETAILS ~20%				26,950
TOTAL CAP CONSTRUCTION				$163,000

DATE: 02-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SB-2 CAPPING
LOCATION: DETERRANT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SB-2 CAPPING ANNUAL O&M COSTS DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
ANNUAL COSTS				
ANNUAL INSPECTION & REPORT	20	HR	75.00	$1,500
ANNUAL MOWING	8	HR	50.00	400
MAINTENANCE ITEMS OCCURING EVERY 5 YEARS				
SITE REVIEW	1	LS	10000.00	$10,000
SAMPLING COLLECTION AND ANALYSIS	2	EA	5000.00	10,000
		SUBTOTAL		$20,000
ANNUALIZED COST OF MAINTENANCE ITEMS OCCURING EVERY 5 YEARS				$3,619
SUBTOTAL ANNUAL COSTS				$5,519
UNDEVELOPED DESIGN DETAILS ~20%				1,481
TOTAL ANNUAL POST CLOSURE MAINTENANCE COSTS				$7,000

DATE: 02-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION SB-4 SOIL WASHING
JOB # 6853-09
LOCATION: DETERRENT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SB-4 SOIL WASHING COST SUMMARY TABLE DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
DIRECT COST OF OPTION SB-4 SOIL WASHING				
TREATABILITY TESTING				$30,000
SITE PREPARATION AND MOB/DEMOB				379,000
CONTAMINATED SOIL DELINEATION				130,000
SOIL EXCAVATION				122,000
SOIL WASHING				2,931,000
BACKFILL				165,000
TOTAL DIRECT COST OF OPTION SB-4 SOIL WASHING				$3,757,000
INDIRECT COST OF OPTION SB-4 SOIL WASHING				
HEALTH AND SAFETY			5.00%	$188,000
LEGAL, ADMIN, PERMITTING			5.00%	188,000
ENGINEERING			10.00%	376,000
SERVICES DURING CONSTRUCTION			10.00%	376,000
TOTAL INDIRECT COST OF OPTION SB-4 SOIL WASHING				$1,128,000
TOTAL CAPITAL (DIRECT + INDIRECT) COST				$4,885,000
OPERATING AND MAINTENANCE COSTS				
TOTAL ANNUAL OPERATING AND MAINTENANCE COSTS				$7,000
TOTAL PRESENT WORTH OF O&M COSTS (5% FOR THIRTY YEARS)				$108,000
TOTAL COST OF OPTION SB-4 SOIL WASHING				$4,993,000

DATE:02-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION SB-4 SOIL WASHING
JOB # 6853-09

LOCATION: DETERRENT BURNING GROUND
BADGER ARMY AMMUNITION PLANT

ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SB-4 SOIL WASHING SITE PREPARATION AND MOB/DEMOB DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
EQUIPMENT (IN OR OUT)				
FRONT END LOADER	4	EA	520.00	$2,080
DUMP TRUCKS	20	EA	260.00	5,200
BACKHOE	2	EA	520.00	1,040
DOZER	2	EA	1000.00	2,000
OFFICE TRAILER	6	MON	155.00	930
STORAGE TRAILER (2 EA)	12	MON	155.00	1,860
TRAILER SET-UP & DELIVERY, REMOVAL	3	EA	310.00	930
TOILET (2 EA*6 MON/EA*4.2 WK/MON)	50	WK	25.00	1,250
WATER CLR (2EA*6MON/EA*4.2WK/MON)	50	WK	25.00	1,250
WATER (50 WK * 5 DAY/WK)	300	DAY	15.00	4,500
TELEPHONE SERVICE	6	MON	520.00	3,120
ELECTRICAL HOOK-UP	1	LS	2500.00	2,500
ELECTRICAL POWER	6	MON	300.00	1,800
PICK-UP (2 EA * 6 MON/EA)	12	MON	1035.00	12,420
OFFICE EQUIPMENT	6	MON	1035.00	6,210
PUMPS, TOOLS MINOR EQUIPMENT	1	LS	5000.00	5,000
CONTAMINATED SOIL STOCKPILE AREA				
CLEAR & GRUB LIGHT VEGETATION	1	AC	3825.00	3,825
GRADE	1650	CY	2.00	3,300
GRAVEL - 12" THICK	4840	SY	3.50	16,940
PARKING AREA				
CLEAR & GRUB LIGHT VEGETATION	0.25	AC	3825.00	956
GRADE	420	CY	2.00	840
GRAVEL - 12" THICK	1210	SY	3.50	4,235
TREATED SOIL STOCKPILE AREA				
CLEAR & GRUB LIGHT VEGETATION	0.5	AC	3825.00	1,913
GRADE	825	CY	2.00	1,650
GRAVEL - 12" THICK	2420	SY	3.50	8,470
DECON PAD	1	LS	10000.00	10,000
TOTAL THIS PAGE				$104,219

DATE: 02-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION SB-4 SOIL WASHING
LOCATION: DETERRENT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

JOB # 6853-09

ESTIMATOR: P. R. MARTIN

OPTION SB-4 SOIL WASHING SITE PREPARATION AND MOB/DEMOB DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
TOTAL PAGE 2				$104,219
SOIL WASHING SITE				
CLEAR & GRUB LIGHT VEGETATION	1	AC	3825.00	3,825
GRADE	1650	CY	2.00	3,300
GRAVEL - 12" THICK	4840	SY	3.50	16,940
LABORER (2 MEN*10 DAY/MAN*8 HR/DAY)	160	MNHR	30.50	4,880
CARPENTER (2 MEN*10 DAY/MAN*8 HR/DAY)	160	MNHR	39.00	6,240
ELECTRICIAN (2 MEN*10 DAY/MAN*8 HR/DAY	160	MNHR	42.50	6,800
SITE SUPERINTENDANT (6 MON*210 HR/MON)	1260	MNHR	62.25	78,435
FOREMAN (6 MON * 210 HR/MON)	1260	MNHR	51.75	65,205
CLERK/TYPIST (6 MON * 168 HR/MON)	1008	MNHR	26.00	26,208
UNDEVELOPED DESIGN DETAILS ~20%				62,948
TOTAL SITE PREPARATION AND MOB/DEMOB				$379,000

DATE:02-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SB-4 SOIL WASHING
LOCATION: DETERRENT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SB-4 SOIL WASHING

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
CONTAMINATED SOIL DELINEATION				
DRILLING COSTS	63	BRG	1425.00	$89,775
ON-SITE SAMPLE ANALYSIS	10	DAY	1450.00	14,500
OFF-SITE CONFIRMATORY ANALYSIS	25	SMPL	175.00	4,375
UNDEVELOPED DESIGN DETAILS ~20%				21,350
TOTAL CONTAMINATED SOIL DELINEATION				$130,000
TREATABILITY TESTING				
BENCH SCALE TEST	1	LS	5000.00	$5,000
PILOT SCALE TEST	1	LS	20000.00	20,000
UNDEVELOPED DESIGN DETAILS ~20%				5,000
TOTAL TREATABILITY TESTING				$30,000

DATE: 02-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SB-4 SOIL WASHING
LOCATION: DETERRENT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SB-4 SOIL WASHING SOIL EXCAVATION DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
SOIL EXCAVATION				
BACKHOE & OPERATOR	20	DAY	1350.00	$27,000
LABORER	320	HR	30.00	9,600
DUMP TRUCK & DRIVER (5 EA)	100	DAY	650.00	65,000
UNDEVELOPED DESIGN DETAILS ~20%				20,400
TOTAL SOIL EXCAVATION				$122,000

DATE: 02-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION SB-4 SOIL WASHING
LOCATION: DETERRENT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

JOB # 6853-09

ESTIMATOR: P. R. MARTIN

OPTION SB-4 SOIL WASHING

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
SOIL WASHING	5700	CY	428.50	$2,442,450
TREATMENT OF SECONDARY WASTE INCLUDED IN SOIL WASHING COSTS				
UNDEVELOPED DESIGN DETAILS ~20%				488,550
TOTAL SOIL WASHING				$2,931,000
BACKFILL SOIL				
FRONT END LOADER & OPERATOR	20	DAY	920.00	$18,400
DUMP TRUCK & DRIVER (5 EA)	100	DAY	650.00	65,000
DOZER & OPERATOR	20	DAY	1450.00	29,000
LABORER (2 EA)	320	HR	30.00	9,600
BORROW MATERIAL	560	CY	4.00	2,240
TOP SOIL	1050	CY	10.00	10,500
SEED, FERTILIZE, MULCH	1.3	AC	2000.00	2,600
UNDEVELOPED DESIGN DETAILS ~20%				27,660
TOTAL BACKFILL SOIL				$165,000

DATE:02-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION SB-4 SOIL WASHING

JOB # 6853-09

LOCATION: DETERRENT BURNING GROUND
BADGER ARMY AMMUNITION PLANT

ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SB-4 SOIL WASHING ANNUAL O&M COSTS DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
ANNUAL OPERATING & MAINTENANCE COSTS				
EDUCATIONAL PROGRAMS	1	LS	5000.00	$5,000
FIVE YEAR SITE REVIEW @ $10,000 EVERY FIVE YEARS	1	LS	1809.75	1,810
CONTINGENCY ~10%				190
TOTAL ANNUAL OPERATING & MAINTENANCE COSTS				$7,000

DATE:02-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION SB-7 ON-SITE INCINERATION

JOB # 6853-09

LOCATION: DETERRENT BURNING GROUND
BADGER ARMY AMMUNITION PLANT

ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SB-7 ON-SITE INCINERATION
COST SUMMARY TABLE

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
DIRECT COST OF OPTION SB-7 ON-SITE INCINERATION				
SITE PREPARATION AND MOB/DEMOB				$2,007,000
CONTAMINATED SOIL DELINEATION				130,000
EXCAVATE CONTAMINATED SOIL				220,000
BACKFILL SOIL				167,000
INCINERATION				2,433,000
TOTAL DIRECT COST OF OPTION SB-7 ON-SITE INCINERATION				$4,957,000
INDIRECT COST OF OPTION SB-7 ON-SITE INCINERATION				
HEALTH AND SAFETY			5.00%	$248,000
LEGAL, ADMIN, PERMITTING			5.00%	248,000
ENGINEERING			10.00%	496,000
SERVICES DURING CONSTRUCTION			10.00%	496,000
TOTAL INDIRECT COST OF OPTION SB-7 ON-SITE INCINERATION				$1,488,000
TOTAL CAPITAL (DIRECT + INDIRECT) COST				$6,445,000
OPERATING AND MAINTENANCE COSTS				
TOTAL ANNUAL POST CLOSURE MAINTENANCE COSTS				$7,000
TOTAL PRESENT WORTH OF O&M COSTS (5% FOR THIRTY YEARS)				$108,000
TOTAL COST OF OPTION SB-7 ON-SITE INCINERATION				$6,553,000

DATE:02-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SB-7 ON-SITE INCINERATION
LOCATION: DETERRENT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SB-7 ON-SITE INCINERATION SITE PREPARATION AND MOB/DEMOB DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
EQUIPMENT (IN OR OUT)				
FRONT END LOADER	4	EA	520.00	$2,080
DUMP TRUCKS	20	EA	260.00	5,200
BACKHOE	2	EA	520.00	1,040
DOZER	2	EA	1000.00	2,000
INCINERATOR	1	LS	1300000.00	1,300,000
OFFICE TRAILER	8	MON	155.00	1,240
STORAGE TRAILER (2 EA)	16	MON	155.00	2,480
TRAILER SET-UP & DELIVERY, REMOVAL	3	EA	310.00	930
TOILET (2 EA*8 MON/EA*4.2 WK/MON)	68	WK	25.00	1,700
WATER CLR (2EA*8MON/EA*4.2WK/MON)	68	WK	25.00	1,700
WATER (68 WK * 5 DAY/WK)	340	DAY	15.00	5,100
TELEPHONE SERVICE	8	MON	520.00	4,160
ELECTRICAL HOOK-UP	1	LS	2500.00	2,500
ELECTRICAL POWER	8	MON	300.00	2,400
PICK-UP (2 EA * 8 MON/EA)	16	MON	1035.00	16,560
OFFICE EQUIPMENT	8	MON	1035.00	8,280
PUMPS, TOOLS MINOR EQUIPMENT	1	LS	5000.00	5,000
PARKING AREA				
CLEAR & GRUB LIGHT VEGETATION	0.5	AC	3825.00	1,913
GRADE	825	CY	2.00	1,650
GRAVEL - 12" THICK	2420	SY	3.50	8,470
UNTREATED SOIL STOCKPILE AREA				
CLEAR & GRUB LIGHT VEGETATION	0.25	AC	3825.00	956
GRADE	400	CY	2.00	800
EARTH BERM FROM GRADED SOIL	400	CY	2.00	800
GRAVEL - 12" THICK	1210	SY	3.50	4,235
40 MIL LINER	1210	SY	6.00	7,260
6" SAND	200	CY	10.00	2,000
SUMP	1	LS	2500.00	2,500
DRAIN PIPE	200	LF	5.00	1,000
TOTAL THIS PAGE				$1,393,954

DATE:02-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SB-7 ON-SITE INCINERATION
LOCATION: DETERRENT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SB-7 ON-SITE INCINERATION SITE PREPARATION AND MOB/DEMOB DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
TOTAL PAGE 2				$1,393,954
TREATED SOIL STOCKPILE AREA				
CLEAR & GRUB LIGHT VEGETATION	0.75	AC	3825.00	2,869
GRADE	1225	CY	2.00	2,450
GRAVEL - 12" THICK	3630	SY	3.50	12,705
6" SAND	600	CY	10.00	6,000
DECON PAD	1	LS	10000.00	10,000
LABORER (2 MEN*10 DAY/MAN*8 HR/DAY)	160	MNHR	30.50	4,880
CARPENTER (2 MEN*10 DAY/MAN*8 HR/DAY)	160	MNHR	39.00	6,240
ELECTRICIAN (2 MEN*10 DAY/MAN*8 HR/DAY	160	MNHR	42.50	6,800
SITE SUPERINTENDANT (8 MON*210 HR/MON)	1680	MNHR	62.25	104,580
FOREMAN (8 MON * 210 HR/MON)	1680	MNHR	51.75	86,940
CLERK/TYPIST (8 MON * 168 HR/MON)	1344	MNHR	26.00	34,944
UNDEVELOPED DESIGN DETAILS ~20%				334,639
TOTAL SITE PREPARATION AND MOB/DEMOB				$2,007,000

DATE: 02-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SB-7 ON-SITE INCINERATION
LOCATION: DETERRENT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SB-7 ON-SITE INCINERATION CONTAMINATED SOIL DELINEATION DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
DRILLING	63	BRG	1425.00	$89,775
ON-SITE SAMPLING	10	DAY	1450.00	14,500
OFF-SITE CONFIRMATORY SAMPLING	25	SMPL	175.00	4,375
UNDEVELOPED DESIGN DETAILS ~20%				21,350
TOTAL CONTAMINATED SOIL DELINEATION				$130,000

DATE: 02-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION SB-7 ON-SITE INCINERATION
JOB # 6853-09
LOCATION: DETERRENT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SB-7 ON-SITE INCINERATION
EXCAVATE CONTAMINATED SOIL & BACKFILL

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
EXCAVATE CONTAMINATED SOIL				
BACKHOE & OPERATOR	20	DAY	3000.00	60,000
DUMP TRUCK & DRIVER (4 EA)	80	DAY	650.00	52,000
LABORER (2 EA)	320	HR	30.00	9,600
SCREEN	20	DAY	175.00	3,500
BACKHOE & OPERATOR, 1 SHIFT/DAY	20	SHIFT	800.00	16,000
BACKHOE & OPERATOR, 3 SHIFT/DAY	60	SHIFT	700.00	42,000
UNDEVELOPED DESIGN DETAILS ~20%				36,900
TOTAL EXCAVATE CONTAMINATED SOIL				$220,000
BACKFILL SOIL				
FRONT END LOADER & OPERATOR	20	DAY	920.00	$18,400
DUMP TRUCK & DRIVER (5 EA)	100	DAY	650.00	65,000
DOZER & OPERATOR	20	DAY	1450.00	29,000
LABORER (2 EA)	320	HR	30.00	9,600
BORROW MATERIAL	1120	CY	4.00	4,480
TOP SOIL	1050	CY	10.00	10,500
SEED, FERTILIZE, MULCH	1.3	AC	2000.00	2,600
UNDEVELOPED DESIGN DETAILS ~20%				27,420
TOTAL BACKFILL SOIL				$167,000

DATE: 02-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SB-7 ON-SITE INCINERATION
LOCATION: DETERRENT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SB-7 ON-SITE INCINERATION INCINERATION DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
INCINERATION				
INCINERATION FEE	9400	TON	200.00	$1,880,000
SECONDARY WASTE STREAM DISPOSAL				
TRANSPORTATION	24	LOAD	513.00	12,312
LINER FEE	24	LOAD	50.00	1,200
DISPOSAL	940	TON	142.50	133,950
UNDEVELOPED DESIGN DETAILS ~20%				405,538
TOTAL INCINERATION				$2,433,000

DATE: 02-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SB-7 ON-SITE INCINERATION
LOCATION: DETERRENT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SB-7 ON-SITE INCINERATION POST CLOSURE MAINTENANCE DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
ANNUAL OPERATING & MAINTENANCE COSTS				
EDUCATIONAL PROGRAMS	1	LS	5000.00	$5,000
FIVE YEAR SITE REVIEW @ $10,000 EVERY FIVE YEARS	1	LS	1809.75	1,810
CONTINGENCY ~10%				190
TOTAL ANNUAL OPERATING & MAINTENANCE COSTS				$7,000

DATE: 02-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION SB-8 ON-SITE COMPOSTING

JOB # 6853-09

LOCATION: DETERRENT BURNING GROUND
BADGER ARMY AMMUNITION PLANT

ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SB-8 ON-SITE COMPOSTING COST SUMMARY TABLE DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
DIRECT COST OF OPTION SB-8 ON-SITE COMPOSTING				
SITE PREPARATION AND MOB/DEMOB				$536,000
CONTAMINATED SOIL DELINEATION				130,000
EXCAVATE CONTAMINATED SOIL				235,000
BACKFILL SOIL				163,000
COMPOSTING				1,498,000
TOTAL DIRECT COST OF OPTION SB-8 ON-SITE COMPOSTING				$2,562,000
INDIRECT COST OF OPTION SB-8 ON-SITE COMPOSTING				
HEALTH AND SAFETY			5.00%	$128,000
LEGAL, ADMIN, PERMITTING			5.00%	128,000
ENGINEERING			10.00%	256,000
SERVICES DURING CONSTRUCTION			10.00%	256,000
TOTAL INDIRECT COST OF OPTION SB-8 ON-SITE COMPOSTING				$768,000
TOTAL CAPITAL (DIRECT + INDIRECT) COST				$3,330,000
OPERATING AND MAINTENANCE COSTS				
ANNUAL O&M OF COMPOSTING SYSTEM				$542,000
TOTAL PRESENT WORTH OF O&M COSTS (5% FOR TWO YEARS)				$1,008,000
TOTAL ANNUAL POST CLOSURE MAINTENANCE COSTS				$8,000
TOTAL PRESENT WORTH OF POST CLOSURE O&M COSTS (5% FOR THIRTY YEARS)				$123,000
TOTAL PRESENT WORTH OF O&M COSTS				$1,131,000
TOTAL COST OF OPTION SB-8 ON-SITE COMPOSTING				$4,461,000

DATE: 02-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SB-8 ON-SITE COMPOSTING
LOCATION: DETERRENT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SB-8 ON-SITE COMPOSTING SITE PREPARATION AND MOB/DEMOB DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
EQUIPMENT (IN OR OUT)				
FRONT END LOADER	8	EA	520.00	$4,160
DUMP TRUCKS	40	EA	260.00	10,400
BACKHOE	4	EA	520.00	2,080
DOZER	4	EA	1000.00	4,000
OFFICE TRAILER	6	MON	155.00	930
STORAGE TRAILER (2 EA)	12	MON	155.00	1,860
TRAILER SET-UP & DELIVERY, REMOVAL	3	EA	310.00	930
TOILET (2 EA*6 MON/EA*4.2 WK/MON)	50	WK	25.00	1,250
WATER CLR (2EA*6MON/EA*4.2WK/MON)	50	WK	25.00	1,250
WATER (50 WK * 5 DAY/WK)	250	DAY	15.00	3,750
TELEPHONE SERVICE	6	MON	520.00	3,120
ELECTRICAL HOOK-UP	1	LS	2500.00	2,500
ELECTRICAL POWER	6	MON	300.00	1,800
PICK-UP (2 EA * 6 MON/EA)	12	MON	1035.00	12,420
OFFICE EQUIPMENT	6	MON	1035.00	6,210
PUMPS, TOOLS MINOR EQUIPMENT	1	LS	5000.00	5,000
PARKING AREA				
CLEAR & GRUB LIGHT VEGETATION	0.5	AC	3825.00	1,913
GRADE	825	CY	2.00	1,650
GRAVEL - 12" THICK	2420	SY	3.50	8,470
UNTREATED SOIL STOCKPILE AREA				
CLEAR & GRUB LIGHT VEGETATION	0.5	AC	3825.00	1,913
GRADE	800	CY	2.00	1,600
EARTH BERM FROM GRADED SOIL	800	CY	2.00	1,600
GRAVEL - 12" THICK	2420	SY	3.50	8,470
40 MIL LINER	2420	SY	6.00	14,520
6" SAND	400	CY	10.00	4,000
SUMP	1	LS	2500.00	2,500
DRAIN PIPE	400	LF	5.00	2,000
TOTAL THIS PAGE				$110,295

DATE: 02-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION SB-8 ON-SITE COMPOSTING
LOCATION: DETERRENT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

JOB # 6853-09

ESTIMATOR: P. R. MARTIN

OPTION SB-8 ON-SITE COMPOSTING SITE PREPARATION AND MOB/DEMOB DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
TOTAL PAGE 2				$110,295
TREATED SOIL STOCKPILE AREA				
CLEAR & GRUB LIGHT VEGETATION	0.75	AC	3825.00	2,869
GRADE	1225	CY	2.00	2,450
GRAVEL - 12" THICK	3630	SY	3.50	12,705
6" SAND	600	CY	10.00	6,000
COMPOSTING SITE				
CLEAR & GRUB LIGHT VEGETATION	3	AC	3825.00	11,475
GRADE	4950	CY	2.00	9,900
GRAVEL - 12" THICK	14520	SY	1.75	25,410
ASPHALT PAD	85000	SF	0.80	68,000
DECON PAD	1	LS	10000.00	10,000
LABORER (2 MEN*10 DAY/MAN*8 HR/DAY)	160	MNHR	30.50	4,880
CARPENTER (2 MEN*10 DAY/MAN*8 HR/DAY)	160	MNHR	39.00	6,240
ELECTRICIAN (2 MEN*10 DAY/MAN*8 HR/DAY	160	MNHR	42.50	6,800
SITE SUPERINTENDANT (6 MON*210 HR/MON)	1260	MNHR	62.25	78,435
FOREMAN (6 MON * 210 HR/MON)	1260	MNHR	51.75	65,205
CLERK/TYPIST (6 MON * 168 HR/MON)	1008	MNHR	26.00	26,208
UNDEVELOPED DESIGN DETAILS ~20%				89,128
TOTAL SITE PREPARATION AND MOB/DEMOB				$536,000

DATE:02-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SB-8 ON-SITE COMPOSTING
LOCATION: DETERRENT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SB-8 ON-SITE COMPOSTING CONTAMINATED SOIL DELINEATION DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
DRILLING	63	BRG	1425.00	$89,775
ON-SITE SAMPLING	10	DAY	1450.00	14,500
OFF-SITE CONFIRMATORY SAMPLING	25	SMPL	175.00	4,375
UNDEVELOPED DESIGN DETAILS ~20%				21,350
TOTAL CONTAMINATED SOIL DELINEATION				$130,000

DATE:02-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SB-8 ON-SITE COMPOSTING
LOCATION: DETERRENT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SB-8 ON-SITE COMPOSTING
EXCAVATE CONTAMINATED SOIL & BACKFILL

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
EXCAVATE CONTAMINATED SOIL				
BACKHOE & OPERATOR	20	DAY	3000.00	60,000
DUMP TRUCK & DRIVER (5 EA)	100	DAY	650.00	65,000
LABORER (2 EA)	320	HR	30.00	9,600
SCREEN	20	DAY	175.00	3,500
BACKHOE & OPERATOR, 1 SHIFT/DAY	20	SHIFT	800.00	16,000
BACKHOE & OPERATOR, 3 SHIFT/DAY	60	SHIFT	700.00	42,000
UNDEVELOPED DESIGN DETAILS ~20%				38,900
TOTAL EXCAVATE CONTAMINATED SOIL				$235,000
BACKFILL SOIL				
FRONT END LOADER & OPERATOR	20	DAY	920.00	$18,400
DUMP TRUCK & DRIVER (5 EA)	100	DAY	650.00	65,000
DOZER & OPERATOR	20	DAY	1450.00	29,000
LABORER (2 EA)	320	HR	30.00	9,600
BORROW MATERIAL	560	CY	4.00	2,240
TOP SOIL	860	CY	10.00	8,600
SPREAD & COMPACT TOP SOIL	860	CY	2.00	1,720
SEED, FERTILIZE, MULCH	0.5	AC	2000.00	1,000
UNDEVELOPED DESIGN DETAILS ~20%				27,440
TOTAL BACKFILL SOIL				$163,000

DATE: 02-Aug-94

UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION SB-8 ON-SITE COMPOSTING

JOB # 6853-09

LOCATION: DETERRENT BURNING GROUND
BADGER ARMY AMMUNITION PLANT

ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SB-8 ON-SITE COMPOSTING COMPOSTING DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
COMPOSTING				
WINDROW STRUCTURES				
PURCHASE	4	EA	261670.00	$1,046,680
DELIVERY	1	LS	12000.00	12,000
SOIL TURNING EQUIPMENT	1	LS	180000.00	180,000
FRONT END LOADER	1	LS	120000.00	120,000
HAUL TRUCK	1	LS	80000.00	80,000
SALVAGE VALUE	-50.00%	LS	380000.00	(190,000)
UNDEVELOPED DESIGN DETAILS ~20%				249,320
TOTAL COMPOSTING				$1,498,000

DATE: 02-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SB-8 ON-SITE COMPOSTING
LOCATION: DETERRENT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SB-8 ON-SITE COMPOSTING POST CLOSURE MAINTENANCE DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
ANNUAL OPERATING & MAINTENANCE COSTS				
EDUCATIONAL PROGRAMS	1	LS	5000.00	$5,000
FIVE YEAR SITE REVIEW @ $10,000 EVERY FIVE YEARS	1	LS	1809.75	1,810
CONTINGENCY ~20%				1,190
TOTAL ANNUAL OPERATING & MAINTENANCE COSTS				$8,000
ANNUAL COMPOSTING O&M COSTS				
EQUIPMENT - FUEL, ELECTRICITY, MAINTENANCE	40	WK	4000.00	$160,000
LABOR - 6 EA	40	WK	5500.00	220,000
AMENDMENT	1440	TON	50.00	72,000
CONTINGENCY ~20%				90,000
TOTAL ANNUAL COMPOSTING O&M COSTS				$542,000

DATE: 02-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION GW-1 MINIMAL ACTION
LOCATION: DETERRENT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION GW-1 MINIMAL ACTION
COST SUMMARY TABLE

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
DIRECT COST OF OPTION GW-1 MINIMAL ACTION				
INSTITUTIONAL CONTROLS				$10,000
TOTAL DIRECT COST OF OPTION GW-1 MINIMAL ACTION				$10,000
INDIRECT COST OF OPTION GW-1 MINIMAL ACTION				
HEALTH AND SAFETY			0.00%	$0
LEGAL, ADMIN, PERMITTING			0.00%	0
ENGINEERING			0.00%	0
SERVICES DURING CONSTRUCTION			0.00%	0
TOTAL INDIRECT COST OF OPTION GW-1 MINIMAL ACTION				$0
TOTAL CAPITAL (DIRECT + INDIRECT) COST				$10,000
OPERATING AND MAINTENANCE COSTS				
TOTAL COST REPLACEMENT WELLS				$11,000
TOTAL PRESENT WORTH OF REPLACEMENT WELLS IN YEAR 16 @ 5%				$5,000
TOTAL ANNUAL OPERATING AND MAINTENANCE COSTS				$54,000
TOTAL PRESENT WORTH OF ANNUAL O&M COSTS (5% FOR THIRTY YEARS)				$830,000
TOTAL PRESENT WORTH OF OPERATING AND MAINTENANCE COSTS				$835,000
TOTAL COST OF OPTION GW-1 MINIMAL ACTION				$845,000

DATE: 02-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION GW-1 MINIMAL ACTION
LOCATION: DETERRENT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

JOB # 6853-09

ESTIMATOR: P. R. MARTIN

OPTION GW-1 MINIMAL ACTION

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
INSTITUTIONAL CONTROLS	1	LS	10000.00	$10,000
OPERATING & MAINTENANCE COSTS				
REPLACEMENT WELLS	1	EA	10000.00	$10,000
CONTINGENCY ~10%				1,000
TOTAL COST REPLACEMENT WELLS				$11,000
ANNUAL OPERATING & MAINTENANCE COSTS				
GROUNDWATER SAMPLING & ANALYSIS	1	LS	42000.00	$42,000
EDUCATIONAL PROGRAMS	1	LS	5000.00	5,000
FIVE YEAR SITE REVIEW @ $10,000 EVERY FIVE YEARS	1	LS	1809.75	1,810
CONTINGENCY ~10%				5,190
TOTAL ANNUAL OPERATING & MAINTENANCE COSTS				$54,000

DATE: 02-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION GW-2 GROUNDWATER EXTRACTION, TRANSPORTATION, TREATMENT
LOCATION: DETERRENT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION GW-2 GROUNDWATER EXTRACTION, TRANSPORTATION, TREATMENT
COST SUMMARY TABLE

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
DIRECT COST OF OPTION GW-2 GROUNDWATER EXTRACTION, TRANSPORTATION, TREATMENT				
SITE PREPARATION AND MOB/DEMOB				$200,000
EXTRACTION WELL SYSTEM				753,000
TOTAL DIRECT COST OF OPTION GW-2 GROUNDWATER EXTRACTION, TRANSPORTATION, TREATMENT				$953,000
INDIRECT COST OF OPTION GW-2 GROUNDWATER EXTRACTION, TRANSPORTATION, TREATMENT				
HEALTH AND SAFETY			5.00%	$48,000
LEGAL, ADMIN, PERMITTING			5.00%	48,000
ENGINEERING			10.00%	95,000
SERVICES DURING CONSTRUCTION			10.00%	95,000
TOTAL INDIRECT COST OF OPTION GW-2 GROUNDWATER EXTRACTION, TRANSPORTATION, TREATMENT				$286,000
TOTAL CAPITAL (DIRECT + INDIRECT) COST				$1,239,000
OPERATING AND MAINTENANCE COSTS				
TOTAL ANNUAL POST CLOSURE MAINTENANCE COSTS				$50,000
TOTAL PRESENT WORTH OF O&M COSTS (5% FOR THIRTY YEARS)				$769,000
TOTAL COST OF OPTION GW-2 GROUNDWATER EXTRACTION, TRANSPORTATION, TREATMENT				$2,008,000

DATE:02-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION GW-2 GROUNDWATER EXTRACTION, TRANSPORTATION, TREATMENT
LOCATION: DETERRENT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION GW-2 GROUNDWATER EXTRACTION, TRANSPORTATION, TREATMENT

SITE PREPARATION AND MOB/DEMOB DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
EQUIPMENT (IN OR OUT)				
FRONT END LOADER	2	EA	520.00	$1,040
DUMP TRUCKS	4	EA	260.00	1,040
BACKHOE	2	EA	520.00	1,040
DOZER	2	EA	1000.00	2,000
OFFICE TRAILER	3	MON	155.00	465
STORAGE TRAILER (2 EA)	6	MON	155.00	930
TRAILER SET-UP & DELIVERY, REMOVAL	3	EA	310.00	930
TOILET (2 EA*3 MON/EA*4.2 WK/MON)	25	WK	25.00	625
WATER CLR (2EA*3MON/EA*4.2WK/MON)	25	WK	25.00	625
WATER (25 WK * 5 DAY/WK)	125	DAY	15.00	1,875
TELEPHONE SERVICE	3	MON	520.00	1,560
ELECTRICAL HOOK-UP	1	LS	2500.00	2,500
ELECTRICAL POWER	3	MON	300.00	900
PICK-UP (2 EA * 3 MON/EA)	6	MON	1035.00	6,210
OFFICE EQUIPMENT	3	MON	1035.00	3,105
PUMPS, TOOLS MINOR EQUIPMENT	1	LS	5000.00	5,000
STAGING AREA				
CLEAR & GRUB LIGHT VEGETATION	0.75	AC	3825.00	2,869
GRADE	1235	CY	2.00	2,470
GRAVEL - 12" THICK	3630	SY	3.50	12,705
PARKING AREA				
CLEAR & GRUB LIGHT VEGETATION	0.25	AC	3825.00	956
GRADE	410	CY	2.00	820
GRAVEL - 12" THICK	1210	SY	3.50	4,235

TOTAL THIS PAGE $53,900

DATE:02-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION GW-2 GROUNDWATER EXTRACTION, TRANSPORTATION, TREATMENT
LOCATION: DETERRENT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION GW-2 GROUNDWATER EXTRACTION, TRANSPORTATION, TREATMENT
SITE PREPARATION AND MOB/DEMOB

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
TOTAL PAGE 2				$53,900
DECON PAD	1	LS	10000.00	10,000
LABORER (2 MEN*10 DAY/MAN*8 HR/DAY)	160	MNHR	30.50	4,880
CARPENTER (2 MEN*10 DAY/MAN*8 HR/DAY)	160	MNHR	39.00	6,240
ELECTRICIAN (2 MEN*10 DAY/MAN*8 HR/DAY	160	MNHR	42.50	6,800
SITE SUPERINTENDANT (3 MON*210 HR/MON)	630	MNHR	62.25	39,218
FOREMAN (3 MON * 210 HR/MON)	630	MNHR	51.75	32,603
CLERK/TYPIST (3 MON * 168 HR/MON)	504	MNHR	26.00	13,104
UNDEVELOPED DESIGN DETAILS ~20%				33,256
TOTAL SITE PREPARATION AND MOB/DEMOB				$200,000

DATE:02-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION GW-2 GROUNDWATER EXTRACTION, TRANSPORTATION, TREATMENT
LOCATION: DETERRENT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION GW-2 GROUNDWATER EXTRACTION, TRANSPORTATION, TREATMENT
EXTRACTION WELL SYSTEM

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
INSTALL EXTRACTION WELLS	6	EA	35000.00	$210,000
OVERSIGHT	200	HR	56.00	11,200
PUMPS	6	EA	2000.00	12,000
PIPE LINE, 1" DIA	1000	LF	20.00	20,000
STORAGE TANK, 25000 GAL	2	EA	25000.00	50,000
LEVEL TRANSMITTER	6	EA	750.00	4,500
LEVEL SWITCH	6	EA	500.00	3,000
FLOW TRANSMITTER/INDICATOR	6	EA	1000.00	6,000
FLOW CONTROL VALVE	6	EA	1500.00	9,000
FLOW CONTROLLER	6	EA	2000.00	12,000
INSTRUMENTATION CIRCUITS	18000	LF	5.00	90,000
PROGRAMMABLE LOGIC CONTROLLER	1	LS	25000.00	25,000
POWER CIRCUITS	6000	LF	10.00	60,000
MOTOR CONTROL CENTER	1	LS	20000.00	20,000
CONTROL POWER	400	LF	12.50	5,000
PRE-ENGINEERED BUILDING	1000	SF	75.00	75,000
PUMPS & PIPING	1	LS	15000.00	15,000
UNDEVELOPED DESIGN DETAILS ~20%				125,300
TOTAL EXTRACTION WELL SYSTEM				$753,000

DATE:02-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION GW-2 GROUNDWATER EXTRACTION, TRANSPORTATION, TREATMENT
LOCATION: DETERRENT BURNING GROUND
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION GW-2 GROUNDWATER EXTRACTION, TRANSPORTATION, TREATMENT
ANNUAL OPERATION & MAINTENANCE

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
PUMPING POWER	1	LS	50.00	$50
TANK TRAILER, TRUCK, & DRIVER (1 DAY/WK)	52	DAY	800.00	41,600
UNDEVELOPED DESIGN DETAILS ~20%				8,350
TOTAL ANNUAL OPERATION & MAINTENANCE				$50,000

APPENDIX E.2

MATERIAL USAGE

DETERRENT BURNING GROUND

PROJECT	COMP. BY	JOB NO.
BADGER AAP - DETERRENT BURNING GROUND	MPM	6853-09
	CHK. BY	DATE
	RJM	7/11/94

OBJECTIVE: Determine soil volume to be excavated at the Deterrent Burning Ground

Assumptions:
- Contamination is confined to the pits only
- The burn pits are 50 ft ϕ
- ~~Depth is based on WPAL from NR720~~
- side slopes are 2:1, these are assumed not contaminated and will be returned to the excavation

- Pit No. 1 @ DBB-91-01:

2,6-DNT's above 4.29 to a depth of 42'.
2,4-DNT's above 1 mg/Kg to 42'.
As above 2.5 mg/Kg to 6'
Cr does not exceed remediation goals
NNDPA above 595.92 to 25 ft.
∴ Excavate to a depth of 42 ft. + 2' (between samples)

- Volume $= \frac{\pi d^2}{4} \times h$

$= \frac{\pi (50)^2}{4} \times 44'$

$= 86,393.8 \text{ ft}^3 / 27 \text{ cf/cy}$

$= 3,200 \text{ cy.}$

- Pit No. 2 @ DBB-91-03:

2,6 DNTs above 4.29 to a depth of 18'
2,4 DNTs above 1mg/Kg to 22'
As does not exceed RGS
Cr does not exceed except 1 hit @ 102'

PROJECT	COMP. BY	JOB NO.
Badger AAP - DBG	MPM	6853-09
	CHK. BY	DATE 7/11/94

Excavate to a depth of 22' + 2'

• Volume = $\frac{\pi d^2}{4} \times h$

$= \frac{\pi (50)^2}{4} \times 24$

$= 47,123.9\ ft^3 / 27 =$

$= \underline{1,745\ cy.}$

• Pit No. 3 @ DBB-91-02:

2,6-DNT above 4.29 mg/Kg to 8'
2,4-DNT above 1mg/Kg to 27' (isolated hit after 8')
As above 2.5 mg/Kg to 8'
Cr above 10.4 mg/Kg to 6'

Excavate to a depth of 8 ft. + 2'

• Volume = $\frac{\pi d^2}{4} \times h$

$= \frac{\pi (50)^2}{4} \times 10$

$= 19,635.0\ ft^3/27$

$= \underline{727\ cy.}$

• Total:

5,672 cy. say $\boxed{5,700\ cy.}$

FORM 00.01 REV. 4/81

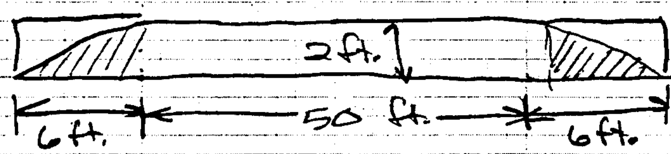
ABB Environmental Services, Inc.

①

PROJECT	COMP. BY	JOB NO.
BADGER – SOIL COVER VOLUME FOR COMPOSTING ALT.	MPM	6853-09
	CHK. BY	DATE,
	AMB	5/20/93

OBJECTIVE: CALCULATE A SOIL COVER VOLUME TO COVER BURN PITS @ DBG

ASSUME: COVER IS 2' DEEP
side slopes are 1:3 (V:H)
To promote runoff



FOR 1 pit: • Volume above excavation
50' ϕ excavation @ 2' deep

$$V = \frac{\pi(50)^2}{4} \times 2'$$

$= 3927\ ft^3$ ✓

volume of above excavation
62' ϕ @ 2' deep

$$V = \frac{\pi(62)^2}{4} \times 2$$

$= 6038\ ft^3$

volume of side slopes = difference btween 62' ϕ and 50' ϕ volumes divided by 2

$= 1055\ ft^3$

~~• Volume of side slopes~~

~~Area of section ≈ 2, 6 ⇒ ½bh~~

~~$\frac{1}{2} \cdot 6(2)$ ✓~~

~~$= 6\ ft^2$ ✓~~

~~Circumference of 50 ϕ excavation~~

~~$= \pi(50)$ ✓~~

~~$= 157.1\ ft.$ ✓~~

$V = 157.1\ ft\ (6\ ft^2)$ ✓

$= 942.5\ ft^3$ ✓

2

PROJECT	COMP. BY	JOB NO.
BADGER - SOIL COVER Volume for composting Act	MPM	6853-09
	CHK. BY	DATE 5/20/93

- Total Volume of 1 pit

$3927 + \cancel{943}\ 1055$

$= \cancel{4868}\ \cancel{4870}\ 4982\ ft^3$

- Total Volume of 3 pits

$4982\ \cancel{4870}\ \cancel{4868}\ ft^3 \times 3$

$= \cancel{14604}\ \cancel{14610}\ 14946\ ft^3 / 27 = 540.8$ c.y. ~~541~~ 554

using ~ 33% fluff factor

need ~~719 c.y.~~ 736 c.y.

≈ ~~720~~ c.y.
740 c.y.

720 is okay since fluff factor may not be so high (1/4 soil is top soil w/ a 15% fluff)

APPENDIX E.3

VENDOR INFORMATION

DETERRENT BURNING GROUND

ABB Environmental Services, Inc.

261 Commercial Street/P.O. Box 7050
Portland, Maine 04112
(207) 775-5401 Telex 94-4329

TELEPHONE MEMORANDUM

PROJECT NO. 6853-09 DATE: 5/20/93

CLIENT: USATHAMA

PROJECT DESCRIPTION: BAAP

BETWEEN: MAUREEN MCGLONE

AND: JILL BESCH @ Geraghty & Miller (813) 961-1921

SUBJECT: Soil washing pilot unit

DISCUSSION: Gave Ms. Besch the volume to be remediated & the contaminant. She worked up a cost estimate for a pilot unit assuming ~~5tons~~ 5tons/hr and 50 tons/day. Operation for 16 weeks would be $1.2 million this would include mobilization and labor costs. O&M costs would be the same for utilities as the full plant (1000 hp).
The full facility requires 1.5 acres but the pilot unit will essentially fit in the parking lot.

DISTRIBUTION:

INTRODUCTION

This Statement of Qualifications and Experience presents the details of the introduction of a new soil treatment technology to the U.S. market. I would like to introduce a concept of three tiers of contaminated soil treatment; traditional treatment technologies, alternative treatment technologies,and emerging treatment technologies. Traditional treatment consists of landfilling, incineration, and stabilization. Alternative technologies consist of low-temperature thermal treatment, bioremediation, vapor extraction, and physical screening and separation to achieve volume reduction...the essence of soil washing. Emerging technologies currently include in-situ vitrification, RF processes, dechlorination, and possibly some extraction techniques. This summary focuses on the alternative soil technologies. One of the most important lessons we have learned over the past decade is that no single technology provides a broad enough capability to solve all the soil situations that we encounter - - the key to feasible and cost-effective site solutions is the ability to optimize the use of reasonable alternatives in a site-specific matrix of use.

The U.S. Environmental Protection Agency (USEPA) has recognized this need and particularly with SARA, emphasized the importance of "on-site" treatment technologies. This policy was initially stimulated through the development of the SITES program and most recently expanded by the formation of the Technology Innovation Office.

Still, all technologies have their limitations. The limitations that are most commonly encountered are:

- The volume of soil is too big or too small.
- The contaminant species and/or concentration is not process compatible.
- Organics and inorganics cannot be handled in the same treatment train.
- The process has little or no commercial operations experience.

The following information is intended to provide a description of a commercial soil-washing facility operating in Holland for the past seven years and to demonstrate how many limitations can be overcome with this system.

BACKGROUND

About the same time as the USEPA began an active review of European technologies, Geraghty & Miller spent about one year evaluating various soil treatment facilities operating in The Netherlands, Germany, France, Italy, and the U.K. This search led us to meet the operational group of Heidemij, headquartered in Arnhem, The

Netherlands. Heidemij is an environmental consulting, management, and remediation firm over 100 years old and the market leader in The Netherlands in soil washing and bioremediation. Heidemij has strong research roots in the Dutch university system and has applied that resource to real field implementation. Heidemij currently operates bench scale, pilot, and commercial soil-washing facilities in Holland, and last year treated more than 150,000 tons of contaminated soil. The USEPA has visited the Heidemij facilities on many occasions and has prepared papers providing technology comparisons.

This background led Geraghty & Miller to establish a Joint Venture with Heidemij so we could quickly and efficiently make this technology available to the U.S. market by implementing full-scale projects.

The objective of the Geraghty & Miller Joint Venture is to provide and operate mobile treatment equipment to manage contaminated soils with a wide range of soil properties and contaminant types. Soil washing provides a practical method whereby the entire soil volume can be understood to separate clean materials from contaminated fractions, and then to direct appropriate treatment at the contaminated portion. The process depends on the ability to effect substantial volume reductions and then to place "clean" soil back on site or to effect beneficial reuse in construction-grade materials meeting applicable specifications.

PROCESS DESCRIPTION

PARTICLE SIZE/CONTAMINANT RELATIONSHIP

The Heidemij Soil Wash Process is based upon the fact that a discrete relationship exists between soil particle size and contaminant residence. The nature of this phenomenon is a result of many factors, including the manner in which the waste was disposed, the site soil matrix, the specific contaminant, the soil cation exchange capacity, particle zeta potential, and dynamic stresses placed on the materials at the site. The first step in evaluating the potential application of soil washing at a particular site is to quantify this particle size/contaminant relationship. It is not necessary to understand all the geochemical forces on the material, but simply to perform a standard sieving analysis and to analyze target fractions. Generally, remedial site soils will exist in five primary "fractions":

- **Gross Oversize.** This material is >8" and consists of concrete rubble, tree stumps and branches, scrap steel, and tires.

- **Oversize.** Material in this fraction is >2"(500mm) but <8". This fraction will consist of gravel, cobbles, shredded wood, and slag.

- **Large, Coarse-Grained Soils.** This material is in the range of 1/4" to 2" and is composed of sands and gravels.

- **Coarse-Grained Soils.** This material resides in the range of 40-60 microns up to 1/4" and is sand.

- **Fine-Grained Materials.** Clays and silts with an average particle size of less than 40-60 microns.

Once these particle size fractions have been identified and quantified, the "percent finer" particle size distribution curve is constructed. Each resulting target fraction is then analyzed chemically for appropriate contaminants. The selection of the analytical menu, of course, will be dependent upon existing information, the history of the site, and understanding of the contaminants of concern. The worst case, where no information exists, will require a full quantitation of each of the particle- size fractions. This analytical work does not need to be conducted with the extensive QA/QC that we have grown used to on investigation projects. Level III data (in accordance with the USEPA's Draft Treatability Study Guidance Document) is acceptable at this point. The data is reviewed and then an overlay of the data on the particle-size distribution curve is prepared. The understanding of this step is the real key to soil washing, for in most cases, at least one of the fractions will not be contaminated. The challenge and capability of the soil wash system is to separate the uncontaminated fraction(s), and then to direct appropriate treatment at the contaminated fractions.

PROCESS OVERVIEW

The process is constructed completely of standard, proven equipment, most of which has been used for decades in the mining business. The waste pile is excavated and a working pile is created. The Gross Oversize and Oversize fractions are separated individually using mechanical screening techniques, while the coarse and fine-grained split is obtained with the creative use of hydrocyclones. If required, the coarse-grained materials (the sands and gravels) are treated by froth-flotation techniques. The fine-grained materials are more difficult to treat and will be handled by dewatering, biological, or extraction processes.

The basic soil-wash treatment plant is modular, and easily transportable. The plant is extremely flexible and can be configured to handle a very wide range of needs from simple volume reduction to sophisticated treatment trains. The "basic" plant has a throughput capacity of 20 tons per hour (tph) and in a full treatment mode requires about 1.5 acres of laydown space. On a typical site, the facility area will be graded, a liner placed on the plant area, and run-on and run-off controls provided. The plant does not require any special foundation or support work. All equipment is on engineered skids with quick disconnects and flexible hosing connections as a basic design feature. If the remedial site

is extremely remote, and roads need to be built into the area of contamination, then that clearly expands the scope of the mobilization activities. The plant's primary utility requirements are water and electrical power. Water is completely recycled in the system, and therefore no discharge is required, but make-up water at the rate of approximately 25 gallons per minute (gpm) is necessary. The 20 tph plant has approximately 1,000 connected horsepower and can operate from an organic mobile generator if commercial 440, 3-phase power is not available.

The soil wash system can be used on a very wide range of contaminant species, including heavy metals, semi-volatile organics, including PCBs and pesticides. If volatile organics are included in the waste stream, the material will either be pre-treated by removing the VOCs with a thermal screw, or the entire system may be operated in an enclosed working space with complete air emissions control.

The plant consists of four major sub-systems:

- Screening
- Separation
- Froth Flotation
- Sludge Management

A schematic diagram of the plant is attached as Figure 1. The plant will be generating three residual products that will be managed:

1. Oversize and Gross Oversize material (usually clean)

2. Clean sand (to be beneficially reused)

3. A sludge cake to be appropriately disposed at a permitted Treatment, Storage, or Disposal Facility (TSDF). The sludge cake is where the contaminants finally reside.

THE SECRET IS TO RECYCLE THE OVERSIZE, REUSE THE CLEAN SOIL, AND TO KEEP THE SLUDGE CAKE VOLUME AS SMALL AS POSSIBLE.

Each of the sub-systems will now be explained.

<u>Screening</u>

As mentioned above, a working pile is excavated in the field. This working pile must first be screened to remove the Gross Oversize fraction. This will normally be accomplished using a hopper mounted with a vibrating Grizzly. If annoying hopper blockage results, it

may be necessary to substitute a Kombi screen or Trommel screen to provide a more uninterrupted step. Gross Oversize material is periodically removed from the hopper area and staged for recycling. The "fall through", or the material that is now <8", is conveyed to the next mechanical screening unit, which will generally consist of a double decked vibrated screen with stacking conveyors. The double-decked screen will have two flow paths: 1) an oversize material that is >2" and, 2) a fall-through that is directed by conveyor to the wet-screening unit.

Wet screening is applied to the stream of soil <2". High- pressure water nozzles attack the influent stream, breaking up small clods, dropping out pea-sized gravel, and forming the slurry that is now pumped to the Separation Sub-system.

<u>Separation</u>

The heart of the Heidemij soil wash system, and the area where extensive experience has been developed, is the creative use of hydrocyclones. Conceptually, the use of hydrocyclones is simple: the influent soil/water slurry is pumped to the cyclone and the slurry enters tangentially. In the cyclone, open to atmospheric pressure, the coarse-grained sands are spun out of the bottom, while the fine-grained materials and water are ejected from the top of the unit.

Several details need to be pointed out regarding the special use of the hydrocyclones in this system. First, the cyclones have field-adjustable cone and barrel components such that the "cut-point" interface between coarse and fine-grained materials can be modified consistent with treatment needs. This is extremely important in achieving the smallest volume of sludge cake requiring off-site disposal. Secondly, the hydrocyclones can be arranged in many flow-path configurations depending upon the interface needs and the goal of minimizing coarse-grained carryover into the fines.

Depending upon the soil to be treated, it may also be beneficial to utilize gravity separators on either or both of the coarse/fine fractions. Typical applications might include the removal of a floating organic layer or, at the other end of the density spectrum, dropping lead out from the soil-treatment stream.

<u>Coarse Fraction Treatment</u>

The underflow from the hydrocyclones contains the coarse-grained materials. When treatment is required for this fraction, it is accomplished using proven air flotation treatment units.

The first important decision that must be made in this sub-system is the selection of a surfactant. The selection, made from scores of alternatives, has one objective: the surfactant, when contacted properly with the contaminant/soil mass, reduces the surface tension binding the contaminant to the sand and allows the contaminants to "float" into a

healthy froth which is then removed from the surface of the air-flotation tank. The selection of the appropriate surfactant is made during the treatability study at the bench-scale level.

The air-flotation tank is a long, rectangular tank that is mixed with the use of mechanical aerators and diffused air. Retention time is typically about 30 minutes, but can be adjusted on the treatment unit.

The flotation units require operator experience to obtain optimal performance. Primary control parameters are surfactant dosing, slurry flow rate, air flow rate, and the height of the overflow weir.

Two streams, the overflow froth, and the underflow sand, are the effluents from the treatment unit. The froth is concentrated and usually directed to the sludge management belt filter press where it is dewatered into a 50-60% solids cake. If, however, the contaminants from the coarse and fine-grained fractions are not compatible, then it may not be wise to send the froth to the filter press, but to manage it separately. The underflow from the flotation unit (the sand) is now directed to sand dewatering screens - the dry sand represents the "clean" material that will be reused, the water is recycled back to the wet screening section.

<u>Sludge Management</u>

The overflow from the hydrocyclone, consisting of fine-grained materials and water is now pumped to the sludge management sub-system. As mentioned earlier, the fines represent the most difficult fraction to treat, as a result of complex binding and attachment dynamics and mechanisms. If the distribution of fines to coarse is favorable, it is feasible to simply treat the fines similar to a wastewater sludge by polymer addition, sedimentation, thickening, and dewatering. If the fines/coarse ratio is not that favorable, it may be necessary to consider more sophisticated treatment. Of course, this upgraded treatment will depend upon the contaminants of concern, but it may include biological degradation or metals extraction.

In the primary case (simple treatment), the hydrocyclone overflow is pumped to the sedimentation area, currently consisting of banked Lamella clarifiers. An appropriate polymer has been selected in lab jar testing, and is dosed prior to introduction to the Lamella. The clarified solids are directed to a sludge thickener, while the water overflow is returned to the wet screening area for reuse. The thickened solids are then pumped to the belt filter press, or, more accurately, a pressurized belt filter press. This unit is one of the most important in the entire process in terms of selection. A 15-20% solids influent is converted into a 50-60% dry solids filter cake. This cake contains the target contaminants and therefore must be managed by disposal at a properly permitted off-site disposal facility, depending upon the specific contaminants and their status in regard to current land bans.

Residuals Management

The important decision that must be made in selecting a soil-wash system is the manner in which the residuals from the treatment system will be managed. Remember, there are three primary residuals to be handled:

- The Oversize and Gross Oversize Material
- The Clean Coarse-Grained Material (The Sand)
- The Fine-Grained Material (The Sludge Cake)

For the oversize material, efforts will be taken to reuse the material. Wood and wood products can be shredded, in many areas this material can be used as a supplemental fuel in co-generation facilities. Steel scrap can be sold to mini-mills, and concrete rubble can be crushed for use as aggregate in concrete production.

The clean sand can be used as select backfill, and can usually be returned directly to the area of excavation. If the site conditions do not require the area of excavation to be regraded, the clean material can be used as a construction grade material for other development uses on site, such as roadways or concrete. In some states, with California leading the way, this "clean" material can be sold for off-site uses after meeting certain criteria.

The fine-grained materials, recall that here is where the contaminants reside, will require disposal off-site at a permitted RCRA TSDF. When the job is initially scoped we will make solid determinations regarding the type of disposal or treatment facility that will be required for the specific fine-grained residuals from the site. This scoping decision will usually be limited to a decision between a hazardous waste landfill or a fixed-base incinerator. This decision will hinge upon the determination as to the status of the specific waste(s) with regard to the Land Disposal Restrictions, commonly known as the land bans.

QUALITY CONTROL SAMPLING AND ANALYSIS

Naturally, any decisions in both the selection, qualification, handling, and disposal of treated residuals will be made using analytically quantified information. The specific parameters to be quantified, and the analytical methods to be employed will be made on a site-specific basis. This decision will be made after an understanding of the previous work performed, the nature of the regulatory requirements at the site, and the client/contractor strategy to be followed.

In most cases, routine quality analyses will be performed on the project site relying on GC and AA techniques. Periodic sampling and analyses will be performed on the treated residuals to verify product quality and the compliance with treatment objectives.

APPENDIX F

NITROGLYCERINE POND/ROCKET PASTE AREA

APPENDIX F.1

COSTS

NITROGLYCERINE POND/ROCKET PASTE AREA

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SS-1 MINIMAL ACTION
LOCATION: NITROGLYCERINE POND/ROCKET PASTE AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SS-1 MINIMAL ACTION COST SUMMARY TABLE DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
DIRECT COST OF OPTION SS-1 MINIMAL ACTION				
INSTITUTIONAL CONTROLS				$10,000
FENCE & SIGNS				543,000
TOTAL DIRECT COST OF OPTION SS-1 MINIMAL ACTION				$553,000
INDIRECT COST OF OPTION SS-1 MINIMAL ACTION				
HEALTH AND SAFETY			5.00%	$28,000
LEGAL, ADMIN, PERMITTING			5.00%	28,000
ENGINEERING			10.00%	55,000
SERVICES DURING CONSTR, QA/QC, DOCUMENTATION			10.00%	55,000
TOTAL INDIRECT COST OF OPTION SS-1 MINIMAL ACTION				$166,000
TOTAL CAPITAL (DIRECT + INDIRECT) COST				$719,000
OPERATING AND MAINTENANCE COSTS				
TOTAL ANNUAL OPERATING AND MAINTENANCE COSTS (INCLUDING GROUNDWATER MONITORING)				$111,000
TOTAL PRESENT WORTH OF ANNUAL O&M COSTS (5% FOR THIRTY YEARS)				$1,706,000
TOTAL COST OF OPTION SS-1 MINIMAL ACTION				$2,425,000

DATE:04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SS-1 MINIMAL ACTION
LOCATION: NITROGLYCERINE POND/ROCKET PASTE AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SS-1 MINIMAL ACTION

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
INSTITUTIONAL CONTROLS	1	LS	10000.00	$10,000
FENCE				
FENCE	32800	LF	12.50	$410,000
GATE	10	EA	900.00	9,000
SIGNS	676	EA	50.00	33,800
CONTINGENCY ~20%				90,200
TOTAL FENCE				$543,000
ANNUAL OPERATING & MAINTENANCE COSTS				
GROUNDWATER SAMPLING & ANALYSIS	1	LS	54000.00	$54,000
EDUCATIONAL PROGRAMS	1	LS	5000.00	5,000
SEMI-ANNUAL VISUAL INSPECTION	16	HR	40.00	640
REPAIR FENCE & SIGNS	5.00%	OF	453000.00	22,650
MOWING - 4 TIMES/YEAR	160	HR	50.00	8,000
FIVE YEAR SITE REVIEW @ $10,000 EVERY FIVE YEARS	1	LS	1809.75	1,810
CONTINGENCY ~20%				18,900
TOTAL ANNUAL OPERATING & MAINTENANCE COSTS				$111,000

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION SS-2 SOIL COVER

JOB # 6853-09

LOCATION: NITROGLYCERINE POND/ROCKET PASTE AREA
BADGER ARMY AMMUNITION PLANT

ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SS-2 SOIL COVER COST SUMMARY TABLE DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
DIRECT COST OF OPTION SS-2 SOIL COVER				
SITE PREPARATION AND MOB/DEMOB				$246,000
SOIL COVER PLACEMENT				679,000
ROCKET PASTE ROAD CULVERT				30,000
TOTAL DIRECT COST OF OPTION SS-2 SOIL COVER				$955,000
INDIRECT COST OF OPTION SS-2 SOIL COVER				
HEALTH AND SAFETY			5.00%	$48,000
LEGAL, ADMIN, PERMITTING			5.00%	48,000
ENGINEERING			10.00%	96,000
SERVICES DURING CONSTR, QA/QC, DOCUMENTATION			10.00%	96,000
TOTAL INDIRECT COST OF OPTION SS-2 SOIL COVER				$288,000
TOTAL CAPITAL (DIRECT + INDIRECT) COST				$1,243,000
OPERATING AND MAINTENANCE COSTS				
TOTAL ANNUAL POST CLOSURE MAINTENANCE COSTS				$114,000
TOTAL PRESENT WORTH OF O&M COSTS (5% FOR THIRTY YEARS)				$1,752,000
TOTAL COST OF OPTION SS-2 SOIL COVER				$2,995,000

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION SS-2 SOIL COVER

JOB # 6853-09

LOCATION: NITROGLYCERINE POND/ROCKET PASTE AREA
BADGER ARMY AMMUNITION PLANT

ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SS-2 SOIL COVER SITE PREPARATION AND MOB/DEMOB DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
EQUIPMENT (IN OR OUT)				
FRONT END LOADER	2	EA	520.00	$1,040
DUMP TRUCKS	8	EA	260.00	2,080
DOZER	4	EA	1000.00	4,000
OFFICE TRAILER	3	MON	155.00	465
STORAGE TRAILER (2 EA)	6	MON	155.00	930
TRAILER SET-UP & DELIVERY, REMOVAL	3	EA	310.00	930
TOILET (2 EA*3 MON/EA*4.2 WK/MON)	25	WK	25.00	625
WATER CLR (2EA*3MON/EA*4.2WK/MON)	25	WK	25.00	625
WATER (25 WK * 5 DAY/WK)	125	DAY	15.00	1,875
TELEPHONE SERVICE	3	MON	520.00	1,560
ELECTRICAL HOOK-UP	1	LS	2500.00	2,500
ELECTRICAL POWER	3	MON	300.00	900
PICK-UP (2 EA * 3 MON/EA)	6	MON	1035.00	6,210
OFFICE EQUIPMENT	3	MON	1035.00	3,105
PUMPS, TOOLS MINOR EQUIPMENT	1	LS	5000.00	5,000
BACKFILL SOIL STOCKPILE AREA				
CLEAR & GRUB LIGHT VEGETATION	2	AC	3825.00	7,650
GRADE	3300	CY	2.00	6,600
GRAVEL - 12" THICK	9680	SY	3.50	33,880
VEHICLE PARKING AREA				
CLEAR & GRUB LIGHT VEGETATION	0.5	AC	3825.00	1,913
GRADE	825	CY	2.00	1,650
GRAVEL - 12" THICK	2420	SY	3.50	8,470

TOTAL THIS PAGE $92,008

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION SS-2 SOIL COVER
JOB # 6853-09

LOCATION: NITROGLYCERINE POND/ROCKET PASTE AREA
BADGER ARMY AMMUNITION PLANT

ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SS-2 SOIL COVER SITE PREPARATION AND MOB/DEMOB DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
TOTAL PAGE 2				$92,008
DECON PAD	1	LS	10000.00	10,000
LABORER (2 MEN*10 DAY/MAN*8 HR/DAY)	160	MNHR	30.50	4,880
CARPENTER (2 MEN*10 DAY/MAN*8 HR/DAY)	160	MNHR	39.00	6,240
ELECTRICIAN (2 MEN*10 DAY/MAN*8 HR/DAY	160	MNHR	42.50	6,800
SITE SUPERINTENDANT (3 MON*210 HR/MON)	630	MNHR	62.25	39,218
FOREMAN (3 MON * 210 HR/MON)	630	MNHR	51.75	32,603
CLERK/TYPIST (3 MON * 168 HR/MON)	504	MNHR	26.00	13,104
UNDEVELOPED DESIGN DETAILS ~20%				41,149
TOTAL SITE PREPARATION AND MOB/DEMOB				$246,000

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION SS-2 SOIL COVER
JOB # 6853-09

LOCATION: NITROGLYCERINE POND/ROCKET PASTE AREA
BADGER ARMY AMMUNITION PLANT

ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SS-2 SOIL COVER SOIL COVER PLACEMENT DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
COVER MATERIAL				
COMMON BORROW	73150	CY	4.00	$292,600
VEGETATIVE SOIL	7245	CY	7.50	54,338
FRONT END LOADER & OPERATOR	5	DAY	1600.00	8,000
DUMP TRUCK & DRIVER (5 EA)	25	DAY	650.00	16,250
DOZER & OPERATOR (2 EA)	70	DAY	1450.00	101,500
LABORER (4 EA)	1120	HR	30.00	33,600
SEED, FERTILIZE, MULCH	15.5	AC	2000.00	31,000
MAIN DITCH EROSION CONTROL	14000	SY	1.50	21,000
HAY BALE/SILT FENCE CHECK DAM	30	EA	250.00	7,500
UNDEVELOPED DESIGN DETAILS ~20%				113,213
TOTAL SOIL COVER PLACEMENT				$679,000

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SS-2 SOIL COVER
LOCATION: NITROGLYCERINE POND/ROCKET PASTE AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SS-2 SOIL COVER ROCKET PASTE ROAD CULVERT DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
ROCKET PASTE ROAD CULVERT				
REMOVE EXISTING 36" RCP	240	LF	50.00	$12,000
REPLACE CULVERTS - 24" DIA	240	LF	30.00	7,200
RAISE GRAVEL ROADWAY	400	CY	15.00	6,000
UNDEVELOPED DESIGN DETAILS ~20%				4,800
TOTAL ROCKET PASTE ROAD CULVERT				$30,000

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SS-2 SOIL COVER
LOCATION: NITROGLYCERINE POND/ROCKET PASTE AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SS-2 SOIL COVER POST CLOSURE MAINTENANCE DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
ANNUAL COSTS				
ANNUAL INSPECTION & REPORT	40	HR	75.00	$3,000
MOWING - 4 TIMES/YEAR	160	HR	50.00	8,000
ANNUAL REPAIRS OF SOIL COVER	5.00%	OF	558000.00	27,900
GROUNDWATER MONITORING	1	LS	54000.00	54,000
MAINTENANCE ITEMS OCCURAING EVERY 5 YEARS				
SITE REVIEW	1	LS	10000.00	$10,000
SUBTOTAL				$10,000
ANNUALIZED COST OF MAINTENANCE ITEMS OCCURING EVERY 5 YEARS				1,810
SUBTOTAL ANNUAL COSTS				$94,710
UNDEVELOPED DESIGN DETAILS ~20%				19,290
TOTAL ANNUAL POST CLOSURE MAINTENANCE COSTS				$114,000

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SS-3 STABILIZATION/SOLIDIFICATION WITH DISPOSAL AT PROPELLANT BURNING GROUND
LOCATION: NITROGLYCERINE POND/ROCKET PASTE AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SS-3 S/S WITH DISPOSAL AT PBG
COST SUMMARY TABLE

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
DIRECT COST OF OPTION SS-3 S/S WITH DISPOSAL AT PBG				
TREATABILITY TESTING				$96,000
SITE PREPARATION AND MOB/DEMOB				588,000
CONTAMINATED SOIL DELINEATION				123,000
SEDIMENT REMOVAL				335,000
EXCAVATE SURFACE SOIL				676,000
BACKFILL SOIL				743,000
STABILIZATION/SOLIDIFICATION				6,090,000
CONFIRMATION SAMPLING				219,000
LOAD SOIL/SEDIMENT INTO TREATMENT EQUIPMENT				89,000
LOAD/HAUL TREATED SOIL/SED TO RACE TRACK & SPREAD				425,000
ROCKET PASTE ROAD CULVERT				30,000
ADDITIONAL COVER REQUIRED AT PBG				516,000
TOTAL DIRECT COST OF OPTION SS-3 S/S WITH DISPOSAL AT PBG				$9,930,000
INDIRECT COST OF OPTION SS-3 S/S WITH DISPOSAL AT PBG				
HEALTH AND SAFETY			5.00%	$497,000
LEGAL, ADMIN, PERMITTING			5.00%	497,000
ENGINEERING			10.00%	993,000
SERVICES DURING CONSTR, QA/QC, DOCUMENTATION			10.00%	993,000
TOTAL INDIRECT COST OF OPTION SS-3 S/S WITH DISPOSAL AT PBG				$2,980,000
TOTAL CAPITAL (DIRECT + INDIRECT) COST				$12,910,000
OPERATING AND MAINTENANCE COSTS				
TOTAL ANNUAL POST CLOSURE MAINTENANCE COSTS				$0
TOTAL PRESENT WORTH OF O&M COSTS (5% FOR THIRTY YEARS)				$0
TOTAL COST OF OPTION SS-3 S/S WITH DISPOSAL AT PBG				$12,910,000

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SS-3 STABILIZATION/SOLIDIFICATION WITH DISPOSAL AT PROPELLANT BURNING GROUND
LOCATION: NITROGLYCERINE POND/ROCKET PASTE AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SS-3 S/S WITH DISPOSAL AT PBG
SITE PREPARATION AND MOB/DEMOB

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
EQUIPMENT (IN OR OUT)				
FRONT END LOADER	4	EA	520.00	$2,080
DUMP TRUCKS	46	EA	260.00	11,960
BACKHOE	4	EA	520.00	2,080
DOZER	8	EA	1000.00	8,000
SOLID/STAB EQUIPMENT	1	LS	100000.00	100,000
OFFICE TRAILER	4	MON	155.00	620
STORAGE TRAILER (2 EA)	8	MON	155.00	1,240
TRAILER SET-UP & DELIVERY, REMOVAL	3	EA	310.00	930
TOILET (2 EA*4 MON/EA*4.2 WK/MON)	34	WK	25.00	850
WATER CLR (2EA*4MON/EA*4.2WK/MON)	34	WK	25.00	850
WATER (34 WK * 5 DAY/WK)	170	DAY	15.00	2,550
TELEPHONE SERVICE	4	MON	520.00	2,080
ELECTRICAL HOOK-UP	1	LS	2500.00	2,500
ELECTRICAL POWER	4	MON	300.00	1,200
PICK-UP (2 EA * 4 MON/EA)	8	MON	1035.00	8,280
OFFICE EQUIPMENT	4	MON	1035.00	4,140
PUMPS, TOOLS MINOR EQUIPMENT	1	LS	5000.00	5,000
BACKFILL SOIL STOCKPILE AREA				
CLEAR & GRUB LIGHT VEGETATION	2	AC	3825.00	7,650
GRADE	3300	CY	2.00	6,600
GRAVEL - 12" THICK	9680	SY	3.50	33,880
TREATED SOIL STOCKPILE AREA				
CLEAR & GRUB LIGHT VEGETATION	0.75	AC	3825.00	2,869
GRADE	1225	CY	2.00	2,450
GRAVEL - 12" THICK	3630	SY	3.50	12,705
6" SAND	600	CY	10.00	6,000
UNTREATED SOIL/SEDIMENT STOCKPILE AREA				
CLEAR & GRUB LIGHT VEGETATION	0.25	AC	3825.00	956
GRADE	400	CY	2.00	800
EARTH BERM FROM GRADED SOIL	400	CY	2.00	800
GRAVEL - 12" THICK	1210	SY	3.50	4,235
40 MIL LINER	1210	SY	6.00	7,260
6" SAND	200	CY	10.00	2,000
SUMP	1	LS	2500.00	2,500
DRAIN PIPE	200	LF	5.00	1,000
TOTAL THIS PAGE				$246,065

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SS-3 STABILIZATION/SOLIDIFICATION WITH DISPOSAL AT PROPELLANT BURNING GROUND
LOCATION: NITROGLYCERINE POND/ROCKET PASTE AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SS-3 S/S WITH DISPOSAL AT PBG
SITE PREPARATION AND MOB/DEMOB

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
TOTAL PAGE 2				$246,065
SEDIMENT DEWATERING AREA				
CLEAR & GRUB LIGHT VEGETATION	0.5	AC	3825.00	1,913
GRADE	800	CY	2.00	1,600
EARTH BERM FROM GRADED SOIL	800	CY	2.00	1,600
GRAVEL - 12" THICK	2420	SY	3.50	8,470
40 MIL LINER	2420	SY	6.00	14,520
12" SAND	800	CY	10.00	8,000
SUMP	1	LS	2500.00	2,500
DRAIN PIPE	800	LF	5.00	4,000
STABILIZATION/SOLIDIFICATION PROCESS AREA				
CLEAR & GRUB LIGHT VEGETATION	2	AC	3825.00	7,650
GRADE	3300	CY	2.00	6,600
GRAVEL - 12" THICK	9680	SY	3.50	33,880
VEHICLE PARKING AREA				
CLEAR & GRUB LIGHT VEGETATION	0.5	AC	3825.00	1,913
GRADE	825	CY	2.00	1,650
GRAVEL - 12" THICK	2420	SY	3.50	8,470
DECON PAD	1	LS	10000.00	10,000
LABORER (2 MEN*10 DAY/MAN*8 HR/DAY)	160	MNHR	30.50	4,880
CARPENTER (2 MEN*10 DAY/MAN*8 HR/DAY)	160	MNHR	39.00	6,240
ELECTRICIAN (2 MEN*10 DAY/MAN*8 HR/DAY	160	MNHR	42.50	6,800
SITE SUPERINTENDANT (4 MON*210 HR/MON)	840	MNHR	62.25	52,290
FOREMAN (4 MON * 210 HR/MON)	840	MNHR	51.75	43,470
CLERK/TYPIST (4 MON * 168 HR/MON)	672	MNHR	26.00	17,472
UNDEVELOPED DESIGN DETAILS ~20%				98,018
TOTAL SITE PREPARATION AND MOB/DEMOB				$588,000

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SS-3 STABILIZATION/SOLIDIFICATION WITH DISPOSAL AT PROPELLANT BURNING GROUND
LOCATION: NITROGLYCERINE POND/ROCKET PASTE AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SS-3 S/S WITH DISPOSAL AT PBG
CONTAMINATED SOIL DELINEATION & SEDIMENT REMOV

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
TREATABILITY TESTING				
BENCH SCALE TESTING	1	LS	30000.00	$30,000
PILOT SCALE TESTING	1	LS	50000.00	50,000
UNDEVELOPED DESIGN DETAILS ~20%				16,000
TOTAL TREATABILITY TESTING				$96,000
CONTAMINATED SOIL DELINEATION				
BORINGS	86	EA	450.00	$38,700
SURFACE SAMPLES	8	EA	56.00	448
BORING SAMPLES	186	EA	56.00	10,416
ON SITE LABORATORY	4	WK	10000.00	40,000
OFF SITE ANALYSIS	20	EA	500.00	10,000
INTERPRETATION & REPORT	40	HR	75.00	3,000
UNDEVELOPED DESIGN DETAILS ~20%				20,436
TOTAL CONTAMINATED SOIL DELINEATION				$123,000
REMOVE SEDIMENTS (17500 CY) PLACE IN DEWATERING FACILITY				
BACKHOE & OPERATOR	35	DAY	3000.00	$105,000
DUMP TRUCK & DRIVER (2 EA)	70	DAY	650.00	45,500
LABORER (2 EA)	560	HR	30.00	16,800
DOZER & OPERATOR	35	DAY	1450.00	50,750
MOVE SEDIMENTS FROM DEWATERING FACILITY TO UNTREATED SOIL PILE				
FRONT END LOADER & OPERATOR (2 EA)	20	DAY	1200.00	24,000
DUMP TRUCK & DRIVER (5 EA)	50	DAY	650.00	32,500
LABORER (2 EA)	160	HR	30.00	4,800
UNDEVELOPED DESIGN DETAILS ~20%				55,650
TOTAL SEDIMENT REMOVAL				$335,000

DATE:04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SS-3 STABILIZATION/SOLIDIFICATION WITH DISPOSAL AT PROPELLANT BURNING GROUND
LOCATION: NITROGLYCERINE POND/ROCKET PASTE AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SS-3 S/S WITH DISPOSAL AT PBG
EXCAVATE SURFACE SOILS & BACKFILL

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
EXCAVATE SURFACE SOIL/HAUL TO PBG (55,000 CY)				
BACKHOE & OPERATOR (2 EA)	80	DAY	1600.00	$128,000
DUMP TRUCK & DRIVER (15 EA)	600	DAY	650.00	390,000
LABORER (4 EA)	1280	HR	30.00	38,400
SCREEN	40	DAY	175.00	7,000
UNDEVELOPED DESIGN DETAILS ~20%				112,600
TOTAL EXCAVATE SURFACE SOIL				$676,000
ROCKET PASTE ROAD CULVERT				
REMOVE EXISTING 36" RCP	240	LF	50.00	$12,000
REPLACE CULVERTS - 24" DIA	240	LF	30.00	7,200
RAISE GRAVEL ROADWAY	400	CY	15.00	6,000
UNDEVELOPED DESIGN DETAILS ~20%				4,800
TOTAL ROCKET PASTE ROAD CULVERT				$30,000
BACKFILL SOIL				
FRONT END LOADER & OPERATOR (1 WK)	5	DAY	1600.00	$8,000
DUMP TRUCK & DRIVER (4 EA)	20	DAY	650.00	13,000
COMMON BORROW	75250	CY	4.00	301,000
VEGETATIVE SOIL	8000	CY	7.50	60,000
DOZER & OPERATOR (2 EA)	100	DAY	1300.00	130,000
LABORER (4 EA)	1600	HR	30.00	48,000
SEED, FERTILIZE, MULCH	15.5	AC	2000.00	31,000
MAIN DITCH EROSION CONTROL	14000	SY	1.50	21,000
HAY BALE/SILT FENCE CHECK DAM	30	EA	250.00	7,500
UNDEVELOPED DESIGN DETAILS ~20%				123,500
TOTAL BACKFILL SOIL				$743,000

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SS-3 STABILIZATION/SOLIDIFICATION WITH DISPOSAL AT PROPELLANT BURNING GROUND
LOCATION: NITROGLYCERINE POND/ROCKET PASTE AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SS-3 S/S WITH DISPOSAL AT PBG STABILIZATION/SOLIDIFICATION DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
STABILIZATION/SOLIDIFICATION	72500	CY	70.00	$5,075,000
UNDEVELOPED DESIGN DETAILS ~20%				1,015,000
TOTAL STABILIZATION/SOLIDIFICATION				$6,090,000
CONFIRMATORY SAMPLING				
SAMPLING & TESTING	73	SMPL	2500.00	$182,500
UNDEVELOPED DESIGN DETAILS ~20%				36,500
TOTAL CONFIRMATORY SAMPLING				$219,000
LOAD SOIL/SEDIMENT INTO TREATMENT EQUIPMENT				
FRONT END LOADER & OPER	50	DAY	1250.00	$62,500
LABORER	400	HR	30.00	12,000
UNDEVELOPED DESIGN DETAILS ~20%				14,500
TOTAL LOAD SOIL/SEDIMENT INTO TREATMENT EQUIPMENT				$89,000
LOAD/HAUL TREATED SOIL/SED TO RACE TRACK & SPREAD				
FRONT END LOADER & OPER	50	DAY	1250.00	$62,500
LABORER (2 EA)	800	HR	30.00	24,000
DUMP TRUCK & DRIVER (6 EA)	300	DAY	650.00	195,000
DOZER & OPERATOR	50	DAY	1450.00	72,500
UNDEVELOPED DESIGN DETAILS ~20%				71,000
TOTAL LOAD SOIL/SEDIMENT INTO TREATMENT EQUIPMENT				$425,000
ADDITIONAL COVER REQUIRED AT PBG				
PURCHASE COVER MATERIAL	47700	CY	4.00	$190,800
SPREAD & COMPACT	47700	CY	2.00	95,400
TOP SOIL	10300	CY	10.00	103,000
SPREAD & COMPACT	10300	CY	2.00	20,600
SEED, FERTILIZE, MULCH	10	AC	2000.00	20,000
UNDEVELOPED DESIGN DETAILS ~20%				86,200
TOTAL ADDITIONAL COVER REQUIRED AT PBG				$516,000

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SS-3 STABILIZATION/SOLIDIFICATION WITH DISPOSAL AT PROPELLANT BURNING GROUND
LOCATION: NITROGLYCERINE POND/ROCKET PASTE AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SS-3 S/S WITH DISPOSAL AT PBG POST CLOSURE MAINTENANCE DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
NOTHING REQUIRED - INCLUDED WITH PROPELLANT BURNING GROUND				$0

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SS-4 OFF-SITE DISPOSAL
LOCATION: NITROGLYCERINE POND/ROCKET PASTE AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SS-4 OFF-SITE DISPOSAL COST SUMMARY TABLE DESCRIPTION	UNIT	UNIT COST	TOTAL
DIRECT COST OF OPTION SS-4 OFF-SITE DISPOSAL			
SITE PREPARATION AND MOB/DEMOB			$527,000
CONTAMINATED SOIL DELINEATION			123,000
SEDIMENT REMOVAL			447,000
EXCAVATE SURFACE SOIL			651,000
BACKFILL SOIL			877,000
OFF-SITE DISPOSAL			24,070,000
ROCKET PASTE ROAD CULVERT			30,000
TOTAL DIRECT COST OF OPTION SS-4 OFF-SITE DISPOSAL			$26,725,000
INDIRECT COST OF OPTION SS-4 OFF-SITE DISPOSAL			
HEALTH AND SAFETY		5.00%	$1,336,000
LEGAL, ADMIN, PERMITTING		5.00%	1,336,000
ENGINEERING		10.00%	2,673,000
SERVICES DURING CONSTR, QA/QC, DOCUMENTATION		10.00%	2,673,000
TOTAL INDIRECT COST OF OPTION SS-4 OFF-SITE DISPOSAL			$8,018,000
TOTAL CAPITAL (DIRECT + INDIRECT) COST			$34,743,000
OPERATING AND MAINTENANCE COSTS			
TOTAL ANNUAL POST CLOSURE MAINTENANCE COSTS			$0
TOTAL PRESENT WORTH OF O&M COSTS (5% FOR THIRTY YEARS)			$0
TOTAL COST OF OPTION SS-4 OFF-SITE DISPOSAL			$34,743,000

DATE:04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION SS-4 OFF-SITE DISPOSAL
JOB # 6853-09

LOCATION: NITROGLYCERINE POND/ROCKET PASTE AREA
BADGER ARMY AMMUNITION PLANT

ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SS-4 OFF-SITE DISPOSAL SITE PREPARATION AND MOB/DEMOB DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
EQUIPMENT (IN OR OUT)				
FRONT END LOADER	2	EA	520.00	$1,040
DUMP TRUCKS	4	EA	260.00	1,040
BACKHOE	4	EA	520.00	2,080
DOZER	6	EA	1000.00	6,000
OFFICE TRAILER	8	MON	155.00	1,240
STORAGE TRAILER (2 EA)	16	MON	155.00	2,480
TRAILER SET-UP & DELIVERY, REMOVAL	3	EA	310.00	930
TOILET (2 EA*8 MON/EA*4.2 WK/MON)	68	WK	25.00	1,700
WATER CLR (2EA*8MON/EA*4.2WK/MON)	68	WK	25.00	1,700
WATER (68 WK * 5 DAY/WK)	340	DAY	15.00	5,100
TELEPHONE SERVICE	8	MON	520.00	4,160
ELECTRICAL HOOK-UP	1	LS	2500.00	2,500
ELECTRICAL POWER	8	MON	300.00	2,400
PICK-UP (2 EA * 8 MON/EA)	16	MON	1035.00	16,560
OFFICE EQUIPMENT	8	MON	1035.00	8,280
PUMPS, TOOLS MINOR EQUIPMENT	1	LS	5000.00	5,000
BACKFILL SOIL STOCKPILE AREA				
CLEAR & GRUB LIGHT VEGETATION	2	AC	3825.00	7,650
GRADE	3300	CY	2.00	6,600
GRAVEL - 12" THICK	9680	SY	3.50	33,880
UNTREATED SOIL/SEDIMENT STOCKPILE AREA				
CLEAR & GRUB LIGHT VEGETATION	0.25	AC	3825.00	956
GRADE	400	CY	2.00	800
EARTH BERM FROM GRADED SOIL	400	CY	2.00	800
GRAVEL - 12" THICK	1210	SY	3.50	4,235
40 MIL LINER	1210	SY	6.00	7,260
6" SAND	200	CY	10.00	2,000
SUMP	1	LS	2500.00	2,500
DRAIN PIPE	200	LF	5.00	1,000
TOTAL THIS PAGE				$129,891

DATE:04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION SS-4 OFF-SITE DISPOSAL
JOB # 6853-09

LOCATION: NITROGLYCERINE POND/ROCKET PASTE AREA
BADGER ARMY AMMUNITION PLANT

ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SS-4 OFF-SITE DISPOSAL SITE PREPARATION AND MOB/DEMOB DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
TOTAL PAGE 2				$129,891
SEDIMENT DEWATERING AREA				
CLEAR & GRUB LIGHT VEGETATION	0.5	AC	3825.00	1,913
GRADE	800	CY	2.00	1,600
EARTH BERM FROM GRADED SOIL	800	CY	2.00	1,600
GRAVEL - 12" THICK	2420	SY	3.50	8,470
40 MIL LINER	2420	SY	6.00	14,520
12" SAND	800	CY	10.00	8,000
SUMP	1	LS	2500.00	2,500
DRAIN PIPE	800	LF	5.00	4,000
VEHICLE PARKING AREA				
CLEAR & GRUB LIGHT VEGETATION	0.5	AC	3825.00	1,913
GRADE	825	CY	2.00	1,650
GRAVEL - 12" THICK	2420	SY	3.50	8,470
DECON PAD	1	LS	10000.00	10,000
LABORER (2 MEN*10 DAY/MAN*8 HR/DAY)	160	MNHR	30.50	4,880
CARPENTER (2 MEN*10 DAY/MAN*8 HR/DAY)	160	MNHR	39.00	6,240
ELECTRICIAN (2 MEN*10 DAY/MAN*8 HR/DAY	160	MNHR	42.50	6,800
SITE SUPERINTENDANT (8 MON*210 HR/MON)	1680	MNHR	62.25	104,580
FOREMAN (8 MON * 210 HR/MON)	1680	MNHR	51.75	86,940
CLERK/TYPIST (8 MON * 168 HR/MON)	1344	MNHR	26.00	34,944
UNDEVELOPED DESIGN DETAILS ~20%				88,090
TOTAL SITE PREPARATION AND MOB/DEMOB				$527,000

DATE:04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION SS-4 OFF-SITE DISPOSAL
JOB # 6853-09

LOCATION: NITROGLYCERINE POND/ROCKET PASTE AREA
BADGER ARMY AMMUNITION PLANT

ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SS-4 OFF-SITE DISPOSAL SEDIMENT REMOVAL DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
CONTAMINATED SOIL DELINEATION				
BORINGS	86	EA	450.00	$38,700
SURFACE SAMPLES	8	EA	56.00	448
BORING SAMPLES	186	EA	56.00	10,416
ON SITE LABORATORY	4	WK	10000.00	40,000
OFF SITE ANALYSIS	20	EA	500.00	10,000
INTERPRETATION & REPORT	40	HR	75.00	3,000
UNDEVELOPED DESIGN DETAILS ~20%				20,436
TOTAL CONTAMINATED SOIL DELINEATION				$123,000
REMOVE SEDIMENTS (17500 CY) PLACE IN DEWATERING FACILITY				
BACKHOE & OPERATOR	20	DAY	3000.00	$60,000
DUMP TRUCK & DRIVER (2 EA)	40	DAY	650.00	26,000
LABORER (2 EA)	320	HR	30.00	9,600
DOZER & OPERATOR	20	DAY	1450.00	29,000
STABILIZATION CEMENT	17500	CY	10.00	175,000
LOAD SEDIMENTS FOR TRANSPORTATION				
FRONT END LOADER & OPERATOR	35	DAY	1600.00	56,000
LABORER (2 EA)	560	HR	30.00	16,800
UNDEVELOPED DESIGN DETAILS ~20%				74,600
TOTAL SEDIMENT REMOVAL				$447,000

DATE:04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION SS-4 OFF-SITE DISPOSAL
LOCATION: NITROGLYCERINE POND/ROCKET PASTE AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

JOB # 6853-09

ESTIMATOR: P. R. MARTIN

OPTION SS-4 OFF-SITE DISPOSAL EXCAVATE SURFACE SOILS & BACKFILL DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
EXCAVATE SURFACE SOIL (55,000 CY)				
DOZER & OPERATOR	110	DAY	1450.00	$159,500
BACKHOE & OPERATOR	110	DAY	3000.00	330,000
LABORER (2 EA)	1760	HR	30.00	52,800
UNDEVELOPED DESIGN DETAILS ~20%				108,700
TOTAL EXCAVATE SURFACE SOIL				$651,000
ROCKET PASTE ROAD CULVERT				
REMOVE EXISTING 36" RCP	240	LF	50.00	$12,000
REPLACE CULVERTS - 24" DIA	240	LF	30.00	7,200
RAISE GRAVEL ROADWAY	400	CY	15.00	6,000
UNDEVELOPED DESIGN DETAILS ~20%				4,800
TOTAL ROCKET PASTE ROAD CULVERT				$30,000
BACKFILL SOIL				
FRONT END LOADER & OPERATOR (1 WK)	5	DAY	1600.00	$8,000
DUMP TRUCK & DRIVER (4 EA)	20	DAY	650.00	13,000
COMMON BORROW	75250	CY	4.00	301,000
VEGETATIVE SOIL	8000	CY	7.50	60,000
DOZER & OPERATOR (2 EA)	150	DAY	1450.00	217,500
LABORER (4 EA)	2400	HR	30.00	72,000
SEED, FERTILIZE, MULCH	15.5	AC	2000.00	31,000
MAIN DITCH EROSION CONTROL FABRIC	14000	SY	1.50	21,000
HAY BALE/SILT FENCE CHECK FENCE	30	EA	250.00	7,500
UNDEVELOPED DESIGN DETAILS ~20%				146,000
TOTAL BACKFILL SOIL				$877,000

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SS-4 OFF-SITE DISPOSAL
LOCATION: NITROGLYCERINE POND/ROCKET PASTE AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SS-4 OFF-SITE DISPOSAL OFF-SITE DISPOSAL DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
OFF-SITE DISPOSAL				
TRANSPORTATION	5900	LOAD	513.00	$3,026,700
LINER FEE	5900	LOAD	50.00	295,000
DISPOSAL	117450	TON	142.50	16,736,625
				4,011,675
TOTAL OFF-SITE DISPOSAL				$24,070,000

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SS-4 OFF-SITE DISPOSAL
LOCATION: NITROGLYCERINE POND/ROCKET PASTE AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SS-4 OFF-SITE DISPOSAL POST CLOSURE MAINTENANCE DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
NONE REQUIRED				

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SS-5 IN-SITU STABILIZATION/SOLIDIFICATION AND SOIL COVER
LOCATION: NITROGLYCERINE POND/ROCKET PASTE AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SS-5 IN-SITU STABILIZATION/SOLIDIFICATION AND SOIL COVER
COST SUMMARY TABLE

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
DIRECT COST OF OPTION SS-5 IN-SITU STABILIZATION/SOLIDIFICATION AND SOIL COVER				
TREATABILITY STUDY				$96,000
SITE PREPARATION AND MOB/DEMOB				516,000
CONTAMINATED SOIL DELINEATION				123,000
ROCKET PASTE ROAD CULVERT				30,000
STABILIZATION/SOLIDIFICATION				3,255,000
CONFIRMATION SAMPLING				219,000
SOIL COVER CONSTRUCTION				1,287,000
TOTAL DIRECT COST OF OPTION SS-5 IN-SITU STABILIZATION/SOLIDIFICATION AND SOIL COVER				$5,526,000
INDIRECT COST OF OPTION SS-5 IN-SITU STABILIZATION/SOLIDIFICATION AND SOIL COVER				
HEALTH AND SAFETY			5.00%	$276,000
LEGAL, ADMIN, PERMITTING			5.00%	276,000
ENGINEERING			10.00%	553,000
SERVICES DURING CONSTR, QA/QC, DOCUMENTATION			10.00%	553,000
TOTAL INDIRECT COST OF OPTION SS-5 IN-SITU STABILIZATION/SOLIDIFICATION AND SOIL COVER				$1,658,000
TOTAL CAPITAL (DIRECT + INDIRECT) COST				$7,184,000
OPERATING AND MAINTENANCE COSTS				
TOTAL ANNUAL POST CLOSURE MAINTENANCE COSTS (INCLUDING GROUNDWATER MONITORING)				$144,000
TOTAL PRESENT WORTH OF O&M COSTS (5% FOR THIRTY YEARS)				$2,214,000
TOTAL COST OF OPTION SS-5 IN-SITU STABILIZATION/SOLIDIFICATION AND SOIL COVER				$9,398,000

DATE:04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SS-5 IN-SITU STABILIZATION/SOLIDIFICATION AND SOIL COVER
LOCATION: NITROGLYCERINE POND/ROCKET PASTE AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SS-5 IN-SITU STABILIZATION/SOLIDIFICATION AND SOIL COVER
SITE PREPARATION AND MOB/DEMOB

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
EQUIPMENT (IN OR OUT)				
FRONT END LOADER	2	EA	520.00	$1,040
DUMP TRUCKS	8	EA	260.00	2,080
DOZER	4	EA	1000.00	4,000
SOLID/STAB EQUIPMENT	1	LS	100000.00	100,000
OFFICE TRAILER	6	MON	155.00	930
STORAGE TRAILER (2 EA)	12	MON	155.00	1,860
TRAILER SET-UP & DELIVERY, REMOVAL	3	EA	310.00	930
TOILET (2 EA*3 MON/EA)	52	WK	25.00	1,300
WATER CLR (2EA*3MON/EA)	52	WK	25.00	1,300
WATER (52 WK * 5 DAY/WK)	260	DAY	15.00	3,900
TELEPHONE SERVICE	6	MON	520.00	3,120
ELECTRICAL HOOK-UP	1	LS	2500.00	2,500
ELECTRICAL POWER	6	MON	300.00	1,800
PICK-UP (2 EA * 3 MON/EA)	12	MON	1035.00	12,420
OFFICE EQUIPMENT	6	MON	1035.00	6,210
PUMPS, TOOLS MINOR EQUIPMENT	1	LS	5000.00	5,000
BACKFILL SOIL STOCKPILE AREA				
CLEAR & GRUB LIGHT VEGETATION	2	AC	3825.00	7,650
GRADE	3300	CY	2.00	6,600
GRAVEL - 12" THICK	9680	SY	3.50	33,880
TOTAL THIS PAGE				$196,520

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SS-5 IN-SITU STABILIZATION/SOLIDIFICATION AND SOIL COVER
LOCATION: NITROGLYCERINE POND/ROCKET PASTE AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SS-5 IN-SITU STABILIZATION/SOLIDIFICATION AND SOIL COVER
SITE PREPARATION AND MOB/DEMOB

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
TOTAL PAGE 2				$196,520
STABILIZATION/SOLIDIFICATION PROCESS AREA AT NG POND				
CLEAR & GRUB LIGHT VEGETATION	0.5	AC	3825.00	1,913
GRADE	825	CY	2.00	1,650
GRAVEL - 12" THICK	2420	SY	3.50	8,470
STABILIZATION/SOLIDIFICATION PROCESS AREA AT RP POND				
CLEAR & GRUB LIGHT VEGETATION	0.5	AC	3825.00	1,913
GRADE	825	CY	2.00	1,650
GRAVEL - 12" THICK	2420	SY	3.50	8,470
VEHICLE PARKING AREA				
CLEAR & GRUB LIGHT VEGETATION	0.5	AC	3825.00	1,913
GRADE	825	CY	2.00	1,650
GRAVEL - 12" THICK	2420	SY	3.50	8,470
DECON PAD	1	LS	10000.00	10,000
LABORER (2 MEN*10 DAY/MAN*8 HR/DAY)	160	MNHR	30.50	4,880
CARPENTER (2 MEN*10 DAY/MAN*8 HR/DAY)	160	MNHR	39.00	6,240
ELECTRICIAN (2 MEN*10 DAY/MAN*8 HR/DAY	160	MNHR	42.50	6,800
SITE SUPERINTENDANT (6 MON*210 HR/MON)	1260	MNHR	62.25	78,435
FOREMAN (6 MON * 210 HR/MON)	1260	MNHR	51.75	65,205
CLERK/TYPIST (6 MON * 168 HR/MON)	1008	MNHR	26.00	26,208
UNDEVELOPED DESIGN DETAILS ~20%				85,615
TOTAL SITE PREPARATION AND MOB/DEMOB				$516,000

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SS-5 IN-SITU STABILIZATION/SOLIDIFICATION AND SOIL COVER
LOCATION: NITROGLYCERINE POND/ROCKET PASTE AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SS-5 IN-SITU STABILIZATION/SOLIDIFICATION AND SOIL COVER
CONTAMINATED SOIL DELINEATION & SEDIMENT REMOV

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
TREATABILITY STUDY				
BENCH SCALE TESTING	1	LS	30000.00	$30,000
PILOT SCALE TESTING	1	LS	50000.00	50,000
UNDEVELOPED DESIGN DETAILS ~20%				16,000
TOTAL TREATABILITY STUDY				$96,000
CONTAMINATED SOIL DELINEATION				
BORINGS	86	EA	450.00	$38,700
SURFACE SAMPLES	8	EA	56.00	448
BORING SAMPLES	186	EA	56.00	10,416
ON SITE LABORATORY	4	WK	10000.00	40,000
OFF SITE ANALYSIS	20	EA	500.00	10,000
INTERPRETATION & REPORT	40	HR	75.00	3,000
UNDEVELOPED DESIGN DETAILS ~20%				20,436
TOTAL CONTAMINATED SOIL DELINEATION				$123,000

DATE:04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SS-5 IN-SITU STABILIZATION/SOLIDIFICATION AND SOIL COVER
LOCATION: NITROGLYCERINE POND/ROCKET PASTE AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SS-5 IN-SITU STABILIZATION/SOLIDIFICATION AND SOIL COVER
EXCAVATE SURFACE SOILS & BACKFILL

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
ROCKET PASTE ROAD CULVERT				
REMOVE EXISTING 36" RCP	240	LF	50.00	$12,000
REPLACE CULVERTS - 24" DIA	240	LF	30.00	7,200
RAISE GRAVEL ROADWAY	400	CY	15.00	6,000
UNDEVELOPED DESIGN DETAILS ~20%				4,800
TOTAL ROCKET PASTE ROAD CULVERT				$30,000
STABILIZATION/SOLIDIFICATION				
DITCHES	55000	CY	35.00	$1,925,000
PONDS	17500	CY	45.00	787,500
UNDEVELOPED DESIGN DETAILS ~20%				542,500
TOTAL STABILIZATION/SOLIDIFICATION				$3,255,000
CONFIRMATORY SAMPLING				
SAMPLING & TESTING	73	SMPL	2500.00	$182,500
UNDEVELOPED DESIGN DETAILS ~20%				36,500
TOTAL CONFIRMATORY SAMPLING				$219,000

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SS-5 IN-SITU STABILIZATION/SOLIDIFICATION AND SOIL COVER
LOCATION: NITROGLYCERINE POND/ROCKET PASTE AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SS-5 IN-SITU STABILIZATION/SOLIDIFICATION AND SOIL COVER

SOIL COVER PLACEMENT DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
COVER MATERIAL				
COMMON BORROW	130100	CY	4.00	$520,400
VEGETATIVE SOIL	21700	CY	7.50	162,750
FRONT END LOADER & OPERATOR (1 WK)	5	DAY	1600.00	8,000
DUMP TRUCK & DRIVER (4 EA)	20	DAY	650.00	13,000
DOZER & OPERATOR (2 EA)	150	DAY	1450.00	217,500
LABORER (4 EA)	2400	HR	30.00	72,000
SEED, FERTILIZE, MULCH	26.2	AC	2000.00	52,400
MAIN DITCH EROSION CONTROL	12600	SY	1.50	18,900
HAY BALE/SILT FENCE CHECK DAM	30	EA	250.00	7,500
UNDEVELOPED DESIGN DETAILS ~20%				214,550
TOTAL SOIL COVER PLACEMENT				$1,287,000

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SS-5 IN-SITU STABILIZATION/SOLIDIFICATION AND SOIL COVER
LOCATION: NITROGLYCERINE POND/ROCKET PASTE AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SS-5 IN-SITU STABILIZATION/SOLIDIFICATION AND SOIL COVER
POST CLOSURE MAINTENANCE

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
ANNUAL COSTS				
ANNUAL INSPECTION & REPORT	40	HR	75.00	$3,000
ANNUAL MOWING, 4 TIMES/YEAR	160	HR	50.00	8,000
ANNUAL REPAIRS TO SOIL COVER	5.00%	LS	1065000.00	53,250
GROUNDWATER MONITORING	1	LS	54000.00	54,000
MAINTENANCE ITEMS OCCURING EVERY 5 YEARS				
SITE REVIEW	1	LS	10000.00	$10,000
SUBTOTAL				$10,000
ANNUALIZED COST OF MAINTENANCE ITEMS OCCURING EVERY 5 YEARS				1,810
SUBTOTAL ANNUAL COSTS				$120,060
UNDEVELOPED DESIGN DETAILS ~20%				23,940
TOTAL ANNUAL POST CLOSURE MAINTENANCE COSTS				$144,000

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SW-1 MINIMAL ACTION
LOCATION: NITROGLYCERINE POND/ROCKET PASTE AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SW-1 MINIMAL ACTION COST SUMMARY TABLE DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
DIRECT COST OF OPTION SW-1 MINIMAL ACTION				
INSTITUTIONAL CONTROLS				$10,000
FENCING & WARNING SIGNS				96,000
TOTAL DIRECT COST OF OPTION SW-1 MINIMAL ACTION				$106,000
INDIRECT COST OF OPTION SW-1 MINIMAL ACTION				
HEALTH AND SAFETY			5.00%	$5,000
LEGAL, ADMIN, PERMITTING			5.00%	5,000
ENGINEERING			10.00%	11,000
SERVICES DURING CONSTR, QA/QC, DOCUMENTATION			10.00%	11,000
TOTAL INDIRECT COST OF OPTION SW-1 MINIMAL ACTION				$32,000
TOTAL CAPITAL (DIRECT + INDIRECT) COST				$138,000
OPERATING AND MAINTENANCE COSTS				
TOTAL ANNUAL OPERATING AND MAINTENANCE COSTS				$13,000
TOTAL PRESENT WORTH OF ANNUAL O&M COSTS (5% FOR THIRTY YEARS)				$200,000
ANNUAL GROUNDWATER SAMPLING - FIRST 4 YEARS				$3,000
TOTAL PRESENT WORTH OF ANNUAL GW SAMPLING (5% FOR FOUR YEARS)				$11,000
TOTAL COST OF OPTION SW-1 MINIMAL ACTION				$349,000

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SW-1 MINIMAL ACTION
LOCATION: NITROGLYCERINE POND/ROCKET PASTE AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SW-1 MINIMAL ACTION

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
INSTITUTIONAL CONTROLS	1	LS	10000.00	$10,000
FENCING & WARNING SIGNS				
FENCE	6200	LF	12.50	$77,500
GATE	4	EA	900.00	3,600
WARNING SIGNS	124	EA	50.00	6,200
CONTINGENCY ~20%				8,700
TOTAL FENCING & WARNING SIGNS				$96,000
ANNUAL OPERATING & MAINTENANCE COSTS				
ANNUAL SITE INSPECTION	8	HR	50.00	$400
FENCE REPAIR & REPLACEMENT	5.00%	LS	87300.00	4,365
EDUCATIONAL PROGRAMS	1	LS	5000.00	5,000
FIVE YEAR SITE REVIEW @ $10,000 EVERY FIVE YEARS	1	LS	1809.75	1,810
SURFACE WATER SAMPLING @ $3000 EVERY FIVE YEARS	1	LS	542.92	543
CONTINGENCY ~10%				882
TOTAL ANNUAL OPERATING & MAINTENANCE COSTS				$13,000
SURFACE WATER SAMPLING - YEARS 1 THRU	10	SMPL	300.00	$3,000
CONTINGENCY ~10%				0
TOTAL GROUNDWATER SAMPLING - YEARS 1 THRU 4				$3,000

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SW-2 SURFACE WATER TREATMENT
LOCATION: NITROGLYCERINE POND/ROCKET PASTE AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SW-2 SURFACE WATER TREATMENT BY PRECIPITATION/MICROFILTRATION

COST SUMMARY TABLE

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
DIRECT COST OF OPTION SW-2 SURFACE WATER TRTMNT BY PRECIPITATION/MICROFILTRATION				
TREATABILITY STUDY				$12,000
SITE PREPARATION AND MOB/DEMOB				188,000
BYPASS PUMPING				57,000
PUMPING TO TREATMENT FACILITY				51,000
WATER TREATMENT BY PRECIPITATION				314,000
CONFIRMATION SAMPLING				25,000
DISCHARGE TO MAIN DITCH				2,000
TOTAL DIRECT COST OF OPTION SW-2 SURFACE WATER TREATMENT BY PRECIPITATION/MICROFILTRATION				$649,000
INDIRECT COST OF OPTION SW-2 SURFACE WATER TRTMNT BY PRECIPITATN/MICROFILTRTN				
HEALTH AND SAFETY			5.00%	$32,000
LEGAL, ADMIN, PERMITTING			5.00%	32,000
ENGINEERING			10.00%	65,000
SERVICES DURING CONSTR, QA/QC, DOCUMENTATION			10.00%	65,000
TOTAL INDIRECT COST OF OPTION SW-2 SURFACE WATER TREATMENT BY PRECIPITATION/MICROFILTRATION				$194,000
TOTAL CAPITAL (DIRECT + INDIRECT) COST				$843,000
OPERATING AND MAINTENANCE COSTS				
TOTAL ANNUAL POST CLOSURE MAINTENANCE COSTS				$0
TOTAL PRESENT WORTH OF O&M COSTS (5% FOR THIRTY YEARS)				$0
TOTAL COST OF OPTION SW-2 SURFACE WATER TREATMENT BY PRECIPITATION/MICROFILTRATION				$843,000

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION SW-2 SURFACE WATER TREATMENT
JOB # 6853-09

LOCATION: NITROGLYCERINE POND/ROCKET PASTE AREA
BADGER ARMY AMMUNITION PLANT

ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SW-2 SURFACE WATER TREATMENT BY PRECIPITATION/MICROFILTRATION

SITE PREPARATION AND MOB/DEMOB

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
EQUIPMENT (IN OR OUT)				
FRONT END LOADER	2	EA	520.00	$1,040
DUMP TRUCKS	4	EA	260.00	1,040
BACKHOE	2	EA	520.00	1,040
DOZER	2	EA	1000.00	2,000
OFFICE TRAILER	3	MON	155.00	465
STORAGE TRAILER (2 EA)	6	MON	155.00	930
TRAILER SET-UP & DELIVERY, REMOVAL	3	EA	310.00	930
TOILET (2 EA*3 MON/EA*4.2 WK/MON)	25	WK	25.00	625
WATER CLR (2EA*3MON/EA*4.2WK/MON)	25	WK	25.00	625
WATER (25 WK * 5 DAY/WK)	125	DAY	15.00	1,875
TELEPHONE SERVICE	3	MON	520.00	1,560
ELECTRICAL HOOK-UP	1	LS	2500.00	2,500
ELECTRICAL POWER	3	MON	300.00	900
PICK-UP (2 EA * 3 MON/EA)	6	MON	1035.00	6,210
OFFICE EQUIPMENT	3	MON	1035.00	3,105
PUMPS, TOOLS MINOR EQUIPMENT	1	LS	5000.00	5,000
PARKING AREA				
CLEAR & GRUB LIGHT VEGETATION	0.5	AC	3825.00	1,913
GRADE	825	CY	2.00	1,650
GRAVEL - 12" THICK	2420	SY	3.50	8,470
TREATMENT UNIT AREA				
CLEAR & GRUB LIGHT VEGETATION	0.5	AC	3825.00	1,913
GRADE	825	CY	2.00	1,650
GRAVEL - 12" THICK	2420	SY	3.50	8,470
TOTAL THIS PAGE				$53,910

DATE:04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SW-2 SURFACE WATER TREATMENT
LOCATION: NITROGLYCERINE POND/ROCKET PASTE AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SW-2 SURFACE WATER TREATMENT BY PRECIPITATION/MICROFILTRATION
SITE PREPARATION AND MOB/DEMOB

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
TOTAL PAGE 2				$53,910
LABORER (2 MEN*10 DAY/MAN*8 HR/DAY)	160	MNHR	30.50	4,880
CARPENTER (2 MEN*10 DAY/MAN*8 HR/DAY)	160	MNHR	39.00	6,240
ELECTRICIAN (2 MEN*10 DAY/MAN*8 HR/DAY	160	MNHR	42.50	6,800
SITE SUPERINTENDANT (3 MON*210 HR/MON)	630	MNHR	62.25	39,218
FOREMAN (3 MON * 210 HR/MON)	630	MNHR	51.75	32,603
CLERK/TYPIST (3 MON * 168 HR/MON)	504	MNHR	26.00	13,104
UNDEVELOPED DESIGN DETAILS ~20%				31,246
TOTAL SITE PREPARATION AND MOB/DEMOB				$188,000

DATE:04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION SW-2 SURFACE WATER TREATMENT
JOB # 6853-09
LOCATION: NITROGLYCERINE POND/ROCKET PASTE AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SW-2 SURFACE WATER TREATMENT BY PRECIPITATION/MICROFILTRATION

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
TREATABILITY STUDY	1	LS	10000.00	$10,000
UNDEVELOPED DESIGN DETAILS ~20%				2,000
TOTAL TREATABILITY STUDY				$12,000
BYPASS PUMPING				
DAM OFF PONDS	2	EA	5000.00	$10,000
3" DIA DIAPHRAGM PUMP (2 EA)	12	MON	585.00	7,020
3" DIA SUCTION HOSE, 50 LF - 2 EA	12	MON	71.00	852
4" DIA DISCHARGE HOSE, 1050 LF TOT	6	MON	1008.00	6,048
OPERATION, 1 PUMP FULL TIME FOR 3 MONTHS, 1.5 PUMPS 25% TIME FOR 6 MONTHS	3672	HR	0.95	3,488
LABOR, 3 MON @ 160 HR/MON, 3 MON @ 60 HR/MON	660	HR	30.00	19,800
UNDEVELOPED DESIGN DETAILS ~20%				9,792
TOTAL BYPASS PUMPING				$57,000

DATE:04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION SW-2 SURFACE WATER TREATMENT
JOB # 6853-09

LOCATION: NITROGLYCERINE POND/ROCKET PASTE AREA
BADGER ARMY AMMUNITION PLANT

ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SW-2 SURFACE WATER TREATMENT BY PRECIPITATION/MICROFILTRATION

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
PUMPING TO TREATMENT FACILITY				
3" DIA DIAPHRAGM PUMP (2 EA)	6	MON	585.00	$3,510
3" DIA SUCTION HOSE, 50 LF - 2 EA	6	MON	71.00	426
4" DIA DISCHARGE HOSE, 1300 LF TOT	3	MON	1248.00	3,744
OPERATION, 1 PUMP FULL TIME, 1 PUMP 25% TIME	3	MON	855.00	2,565
LABOR, 12 HR/DAY/MON	1080	HR	30.00	32,400
UNDEVELOPED DESIGN DETAILS ~20%				8,355
TOTAL PUMPING TO TREATMENT FACILITY				$51,000

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SW-2 SURFACE WATER TREATMENT
LOCATION: NITROGLYCERINE POND/ROCKET PASTE AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SW-2 SURFACE WATER TREATMENT BY PRECIPITATION/MICROFILTRATION

WATER TREATMENT & DISCHARGE DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
WATER TREATMENT BY PRECIPITATION/MICROFILTRATION				
TREATMENT FEE	1	LS	250000.00	$250,000
SECONDARY WASTE STREAM DISPOSAL				
TRANSPORTATION	2	LOAD	1781.25	3,563
LINER FEE	2	LOAD	50.00	100
DISPOSAL	30	TON	280.00	8,400
UNDEVELOPED DESIGN DETAILS ~20%				51,938
TOTAL WATER TREATMENT BY PRECIPITATION/MICROFILTRATION				$314,000
DISCHARGE WATER TO MAIN DITCH				
12" DIA CMP CULVERT	100	LF	20.00	$2,000
UNDEVELOPED DESIGN DETAILS ~20%				0
TOTAL DISCHARGE WATER TO MAIN DITCH				$2,000
CONFIRMATION SAMPLING	70	EA	300.00	$21,000
UNDEVELOPED DESIGN DETAILS ~20%				4,000
TOTAL CONFIRMATION SAMPLING				$25,000

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SW-2 SURFACE WATER TREATMENT
LOCATION: NITROGLYCERINE POND/ROCKET PASTE AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SW-2 SURFACE WATER TREATMENT BY PRECIPITATION/MICROFILTRATION

POST CLOSURE MAINTENANCE DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
NONE REQUIRED				

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION SW-3 SURFACE WATER TREATMENT JOB # 6853-09
LOCATION: NITROGLYCERINE POND/ROCKET PASTE AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SW-3 SURFACE WATER TREATMENT BY ION EXCHANGE
COST SUMMARY TABLE

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
DIRECT COST OF OPTION SW-3 SURFACE WATER TREATMENT BY ION EXCHANGE				
TREATABILITY STUDY				$12,000
SITE PREPARATION AND MOB/DEMOB				188,000
BYPASS PUMPING				57,000
PUMPING TO TREATMENT FACILITY				51,000
WATER TREATMENT BY ION EXCHANGE				314,000
CONFIRMATION SAMPLING				25,000
DISCHARGE TO MAIN DITCH				2,000
TOTAL DIRECT COST OF OPTION SW-3 SURFACE WATER TREATMENT BY ION EXCHANGE				$649,000
INDIRECT COST OF OPTION SW-3 SURFACE WATER TREATMENT BY ION EXCHANGE				
HEALTH AND SAFETY			5.00%	$32,000
LEGAL, ADMIN, PERMITTING			5.00%	32,000
ENGINEERING			10.00%	65,000
SERVICES DURING CONSTR, QA/QC, DOCUMENTATION			10.00%	65,000
TOTAL INDIRECT COST OF OPTION SW-3 SURFACE WATER TREATMENT BY ION EXCHANGE				$194,000
TOTAL CAPITAL (DIRECT + INDIRECT) COST				$843,000
OPERATING AND MAINTENANCE COSTS				
TOTAL ANNUAL POST CLOSURE MAINTENANCE COSTS				$0
TOTAL PRESENT WORTH OF O&M COSTS (5% FOR THIRTY YEARS)				$0
TOTAL COST OF OPTION SW-3 SURFACE WATER TREATMENT BY ION EXCHANGE				$843,000

DATE:04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SW-3 SURFACE WATER TREATMENT
LOCATION: NITROGLYCERINE POND/ROCKET PASTE AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SW-3 SURFACE WATER TREATMENT BY ION EXCHANGE
SITE PREPARATION AND MOB/DEMOB

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
EQUIPMENT (IN OR OUT)				
FRONT END LOADER	2	EA	520.00	$1,040
DUMP TRUCKS	4	EA	260.00	1,040
BACKHOE	2	EA	520.00	1,040
DOZER	2	EA	1000.00	2,000
OFFICE TRAILER	3	MON	155.00	465
STORAGE TRAILER (2 EA)	6	MON	155.00	930
TRAILER SET-UP & DELIVERY, REMOVAL	3	EA	310.00	930
TOILET (2 EA*3 MON/EA*4.2 WK/MON)	25	WK	25.00	625
WATER CLR (2EA*3MON/EA*4.2WK/MON)	25	WK	25.00	625
WATER (25 WK * 5 DAY/WK)	125	DAY	15.00	1,875
TELEPHONE SERVICE	3	MON	520.00	1,560
ELECTRICAL HOOK-UP	1	LS	2500.00	2,500
ELECTRICAL POWER	3	MON	300.00	900
PICK-UP (2 EA * 3 MON/EA)	6	MON	1035.00	6,210
OFFICE EQUIPMENT	3	MON	1035.00	3,105
PUMPS, TOOLS MINOR EQUIPMENT	1	LS	5000.00	5,000
PARKING AREA				
CLEAR & GRUB LIGHT VEGETATION	0.5	AC	3825.00	1,913
GRADE	825	CY	2.00	1,650
GRAVEL - 12" THICK	2420	SY	3.50	8,470
TREATMENT UNIT AREA				
CLEAR & GRUB LIGHT VEGETATION	0.5	AC	3825.00	1,913
GRADE	825	CY	2.00	1,650
GRAVEL - 12" THICK	2420	SY	3.50	8,470
TOTAL THIS PAGE				$53,910

DATE:04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION SW-3 SURFACE WATER TREATMENT JOB # 6853-09
LOCATION: NITROGLYCERINE POND/ROCKET PASTE AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SW-3 SURFACE WATER TREATMENT BY ION EXCHANGE
SITE PREPARATION AND MOB/DEMOB

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
TOTAL PAGE 2				$53,910
LABORER (2 MEN*10 DAY/MAN*8 HR/DAY)	160	MNHR	30.50	4,880
CARPENTER (2 MEN*10 DAY/MAN*8 HR/DAY)	160	MNHR	39.00	6,240
ELECTRICIAN (2 MEN*10 DAY/MAN*8 HR/DAY	160	MNHR	42.50	6,800
SITE SUPERINTENDANT (3 MON*210 HR/MON)	630	MNHR	62.25	39,218
FOREMAN (3 MON * 210 HR/MON)	630	MNHR	51.75	32,603
CLERK/TYPIST (3 MON * 168 HR/MON)	504	MNHR	26.00	13,104
UNDEVELOPED DESIGN DETAILS ~20%				31,246
TOTAL SITE PREPARATION AND MOB/DEMOB				$188,000

DATE:04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SW-3 SURFACE WATER TREATMENT
LOCATION: NITROGLYCERINE POND/ROCKET PASTE AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SW-3 SURFACE WATER TREATMENT BY ION EXCHANGE

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
TREATABILITY STUDY	1	LS	10000.00	$10,000
UNDEVELOPED DESIGN DETAILS ~20%				2,000
TOTAL TREATABILITY STUDY				$12,000
BYPASS PUMPING				
DAM OFF PONDS	2	EA	5000.00	$10,000
3" DIA DIAPHRAGM PUMP (2 EA)	12	MON	585.00	7,020
3" DIA SUCTION HOSE, 50 LF - 2 EA	12	MON	71.00	852
4" DIA DISCHARGE HOSE, 1050 LF TOT	6	MON	1008.00	6,048
OPERATION, 1 PUMP FULL TIME FOR 3 MONTHS, 1.5 PUMPS 25% TIME FOR 6 MONTHS	3672	HR	0.95	3,488
LABOR, 3 MON @ 160 HR/MON, 3 MON @ 60 HR/MON	660	HR	30.00	19,800
UNDEVELOPED DESIGN DETAILS ~20%				9,792
TOTAL BYPASS PUMPING				$57,000

DATE:04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION SW-3 SURFACE WATER TREATMENT
LOCATION: NITROGLYCERINE POND/ROCKET PASTE AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

JOB # 6853-09

ESTIMATOR: P. R. MARTIN

OPTION SW-3 SURFACE WATER TREATMENT BY ION EXCHANGE

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
PUMPING TO TREATMENT FACILITY				
3" DIA DIAPHRAGM PUMP (2 EA)	6	MON	585.00	$3,510
3" DIA SUCTION HOSE, 50 LF - 2 EA	6	MON	71.00	426
4" DIA DISCHARGE HOSE, 1300 LF TOT	3	MON	1248.00	3,744
OPERATION, 1 PUMP FULL TIME, 1 PUM 25% TIME	3	MON	855.00	2,565
LABOR, 12 HR/DAY/MON	1080	HR	30.00	32,400
UNDEVELOPED DESIGN DETAILS ~20%				8,355
TOTAL PUMPING TO TREATMENT FACILITY				$51,000

DATE:04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SW-3 SURFACE WATER TREATMENT
LOCATION: NITROGLYCERINE POND/ROCKET PASTE AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SW-3 SURFACE WATER TREATMENT BY ION EXCHANGE
WATER TREATMENT & DISCHARGE

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
WATER TREATMENT BY ION EXCHANGE				
TREATMENT FEE	1	LS	250000.00	$250,000
SECONDARY WASTE STREAM DISPOSAL				
TRANSPORTATION	2	LOAD	1781.25	3,563
LINER FEE	2	LOAD	50.00	100
DISPOSAL	30	TON	280.00	8,400
UNDEVELOPED DESIGN DETAILS ~20%				51,938
TOTAL WATER TREATMENT BY ION EXCHANGE				$314,000
CONFIRMATION SAMPLING	70	EA	300.00	$21,000
UNDEVELOPED DESIGN DETAILS ~20%				4,000
TOTAL CONFIRMATION SAMPLING				$25,000
DISCHARGE WATER TO MAIN DITCH				
12" DIA CMP CULVERT	100	LF	20.00	$2,000
UNDEVELOPED DESIGN DETAILS ~20%				0
TOTAL DISCHARGE WATER TO MAIN DITCH				$2,000

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SW-3 SURFACE WATER TREATMENT
LOCATION: NITROGLYCERINE POND/ROCKET PASTE AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SW-3 SURFACE WATER TREATMENT BY ION EXCHANGE
POST CLOSURE MAINTENANCE

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
NONE REQUIRED				

APPENDIX F.2

VENDOR INFORMATION

NITROGLYCERINE POND/ROCKET PASTE AREA

ABB
ASEA BROWN BOVERI

ABB Environmental Services, Inc.
110 Free Street
P.O. Box 7050
Portland, Maine 04112-7050
Telephone (207) 775-5400
Fax (207) 772-4762

TELEPHONE MEMORANDUM

PROJECT NO.: 6853-09

DATE: 5-12-93

CLIENT: BADGER FS NG/RPA

PROJECT DESCRIPTION:

BETWEEN: JEFF ROSENBLUM

AND: PETER KIMBALL, MEMTEK

SUBJECT: SURFACE WATER TREATMENT

Cleanup for AL, FE, HG, MN, PB

Trailor Mount: ion exchange or
membrane system (2 stage precip).
Microfiltration polishing

Concern w/ ion exchange is the algae and
other gunk in the pond water.
Ion exchange does not alter the water
chemistry very much.

Estimates 50 gpm (for 5 million gal, 3 months)

Question about quality of water returned
to pond - additives may be worse
for aquatic stuff

DISTRIBUTION:
ABB

MEMTEK
28 COOK ST.
BILLERICA, MA
01821
508-667-2828
508-667-1731

1478-49

Form 4/6/90

MEMTEK

May 21, 1993

Mr. Jeff Rosenbloom
ABB Environmental
110 Free Street
Portland, ME 04101

Dear Jeff:

MEMTEK can provide a mobile treatment system to treat 5 million gallons of pond water in three (3) months for a budgetary price of $250,000. The system will be a trailer mounted precipitation and microfiltration system. The system is sized to process an average flow rate of 50 gpm. As part of the project, MEMTEK will provide an operator and all chemistry to treat the water. A residual sludge will be generated and must be disposed of by the site owner.

The treatment system will be designed to remove the following metals to the corresponding effluent limits:

Metal	Aluminum	Iron	Mercury	Magnesium	Lead
Pond Concentration (ug/l)	31000	32000	0.3	500	3000
Treated Concentration (ug/l)	748	1000	0.012	50	3.2

The mercury limit is extremely difficult to evaluate. We would expect some removal, but cannot guarantee 0.012 ug/l. The other limits are readily achievable.

The treatment process is described as follows:

> The pond water would be pumped from the site by a trash pump with a flexible suction hose to the reaction system. In the reaction system hydroxide/sulfide precipitation will be utilized to achieve the minimum solubility for the metals. The precipitated metals will then be filtered out of the wastewater and concentrated by MEMTEK's microfiltration system. The treated effluent can be returned to the pond or to a storage tank provided by others.
>
> The concentrated metals will be dewatered with a filter press. The filter cake must be disposed of by the site owner or responsible agent.

MEMTEK CORPORATION
28 COOK STREET · BILLERICA MA 01821 · (508) 667-2828 · FAX (508) 667-1731

MEMTEK

MEMTEK considered utilizing ion exchange technology for this project. The cost of an ion exchange system is approximately the same for capital and operation. We do not think that an IX system will produce the desired results. This is due to the nature of the water and the metal contaminants. The IX process is subject to breakthrough and leakage of metals. This is determined by the selectivity of the resins available and the operating conditions.

I have included some literature on our wastewater treatment systems for your use. If this project becomes viable, I will gladly provide a firm proposal. MEMTEK can also perform treatability studies to determine the optimum process and, if needed, additional equipment and services.

Please contact me if you have any further questions.

Sincerely,

Peter V. Kimball

Peter V. Kimball
Senior Project Manager

Enclosures

PVK/mlc

PRODUCT BULLETIN

MEMTEK

Rinsewater Maintenance System (RMS™)

Maintains high quality metal finishing rinsewaters and eliminates or reduces waste disposal

FEATURES AND BENEFITS

- **Closed-loop: Eliminates or reduces discharge to sewer and associated costs for water, sewer use, and wastewater treatment.**
- **Prolongs process bath service life due to reduced drag-in contaminants.**
- **Reduces reject rate and improves plating quality**
- **Resin combinations for treatment of chrome, cyanide, and acid/alkali rinsewaters.**
- **Easy regeneration with water and chemical conservation features to minimize regenerant volume and reduce operating cost.**
- **Modular design, factory pre-plumbed, and pre-wired for ease of installation.**
- **Optional lift stations and D.I. makeup systems for complete system integration.**
- **Designed to be compatible with your existing waste management system.**

Metal finishing rinsewaters vary in contaminant loading as a function of bath concentration, part configuration, use of dragouts, and rinsewater flow rate. When applied with proper rinsing techniques, Memtek closed-loop ion exchange technology provides and maintains high quality rinsewater to enhance product quality and to reduce bath maintenance.

Memtek has developed a Rinsewater Maintenance System (RMS) specifically for treating metal finishing rinsewaters. The system successfully removes bath contamination and provides high quality water for reuse with elimination of sewer discharge.

With this approach, those contaminants reaching the rinse are removed, thereby creating the opportunity for metal reclaim and reuse. Memtek provides electrolytic plate-out recovery systems for many metals which, in conjunction with the Rinsewater Maintenance System (RMS) and EVAP atmospheric evaporator, can provide fully closed-loop operation for most applications.

Standard Equipment

RMS standard system components are preplumbed and prewired in the factory for easy on-site installation and include the following major components:

- Conductivity monitors and alarms
- One rinsewater recirculation pump
- One prefiltration unit
- Four fiberglass ion exchange columns with semi-automatic regeneration
- Two regenerant pumps
- Two regenerant makeup tanks with level controls
- One lot each proprietary Memtek cation and anion resin
- NEMA rated control panel with microprocessor controller

Optional Equipment

- Rinsewater collection tank with level control
- Spare process pump
- Spent regenerant collection tank
- Memtek EVAP™ Atmospheric Evaporator
- Memtek Plate Out Cell™ System
- Memtek BTS™ Batch Treatment System

ABB
ASEA BROWN BOVERI

ABB Environmental Services, Inc.
110 Free Street
P.O. Box 7050
Portland, Maine 04112-7050
Telephone (207) 775-5400
Fax (207) 772-4762

TELEPHONE MEMORANDUM

PROJECT NO.: 6853-09

DATE: 5-20-93

CLIENT: BADGER FS

PROJECT DESCRIPTION:

BETWEEN: JEFF ROSENBLUM

AND: PETER KIMBALL, MEMTECH

SUBJECT: SURFACE WATER TREATMENT

For precipitation, expect 10 tons worst case sludge production for 5 million gallons.

Ion exchange and precipitation expected to have very similar costs for equipment and operation.

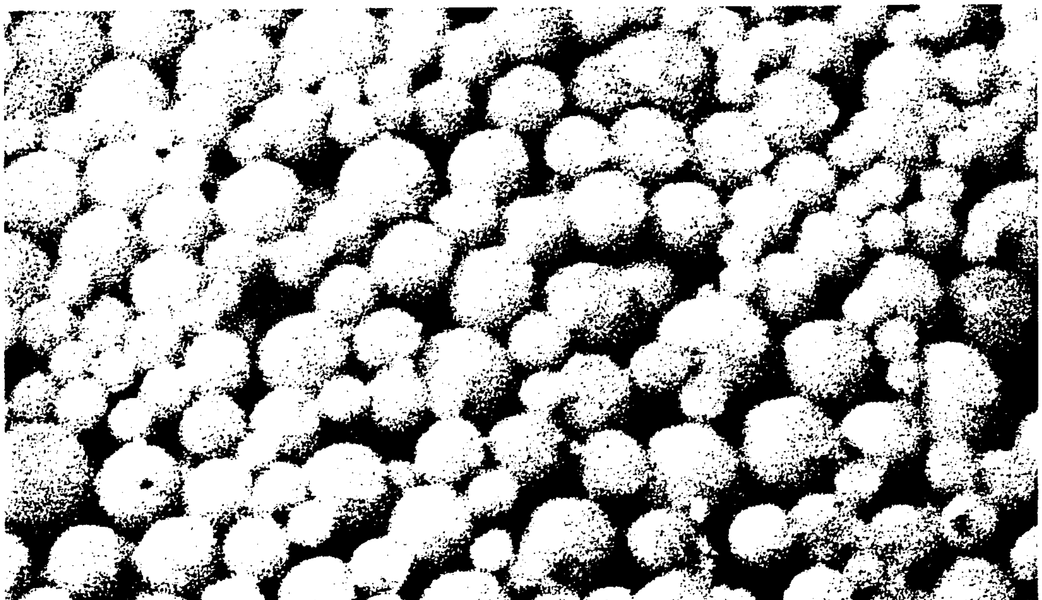
Ion exchange not expected to provide good utilization because of PB and HG kickout before iron breakthrough. Need to regenerate treatment sludge in a batch system.

DISTRIBUTION:
ABB

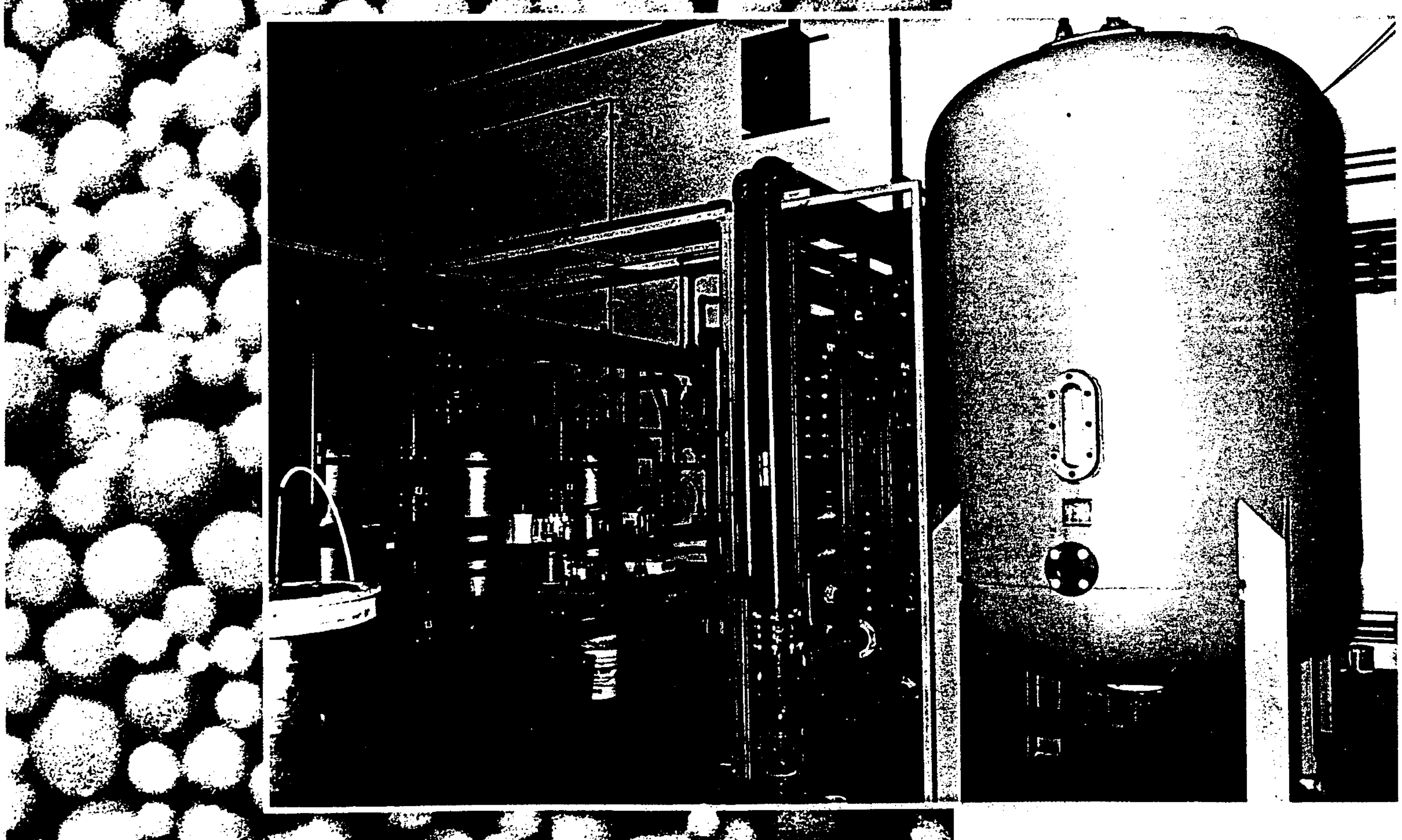
MEMTEK

ION EXCHANGE-ELECTROLYTIC RECOVERY WASTEWATER TREATMENT SYSTEMS

IX/ER®



FOR EFFLUENT COMPLIANCE AND METAL RECOVERY



WASTEWATER TREATMENT & METAL RECOVERY...FOR SELECTED APPLICATIONS

Consistently meets low discharge limits for key toxic metals
Recovers metals in non-hazardous sheets for disposal or sale

The Memtek IX/ER® system provides an outstanding means for complying with the most stringent environmental discharge limits — especially for printed circuit board facility wastewaters. It achieves excellent results in removing copper from segregated streams, reliably removing the copper by ion exchange, and then recovering it in the form of a metal sheet.

Ion exchange resins normally process the majority of waste streams containing complexed copper; however, specific complexes may need to be segregated for treatment by other Memtek systems.

Award-winning, proven technology

IX/ER® systems in operation for years have proven the technology and have established a record for reliable performance.

A complete system

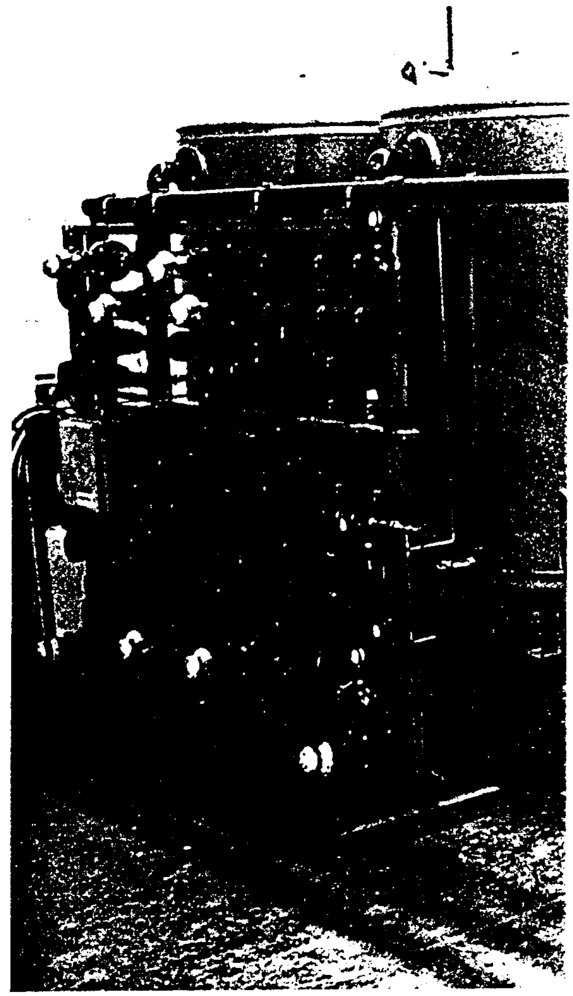
Standard systems include all equipment and automatic controls in compact units.

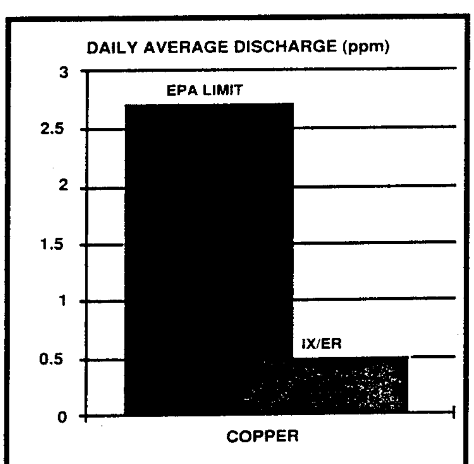
Easy to operate

Advanced microprocessor control reduces operator involvement and assures reliable, automatic, trouble-free performance.

Capacities for any requirement

Standard IX/ER® systems cover a range of flow capacities from 10 to 100 gpm. Designs for capacities to 500 gpm or higher are available.





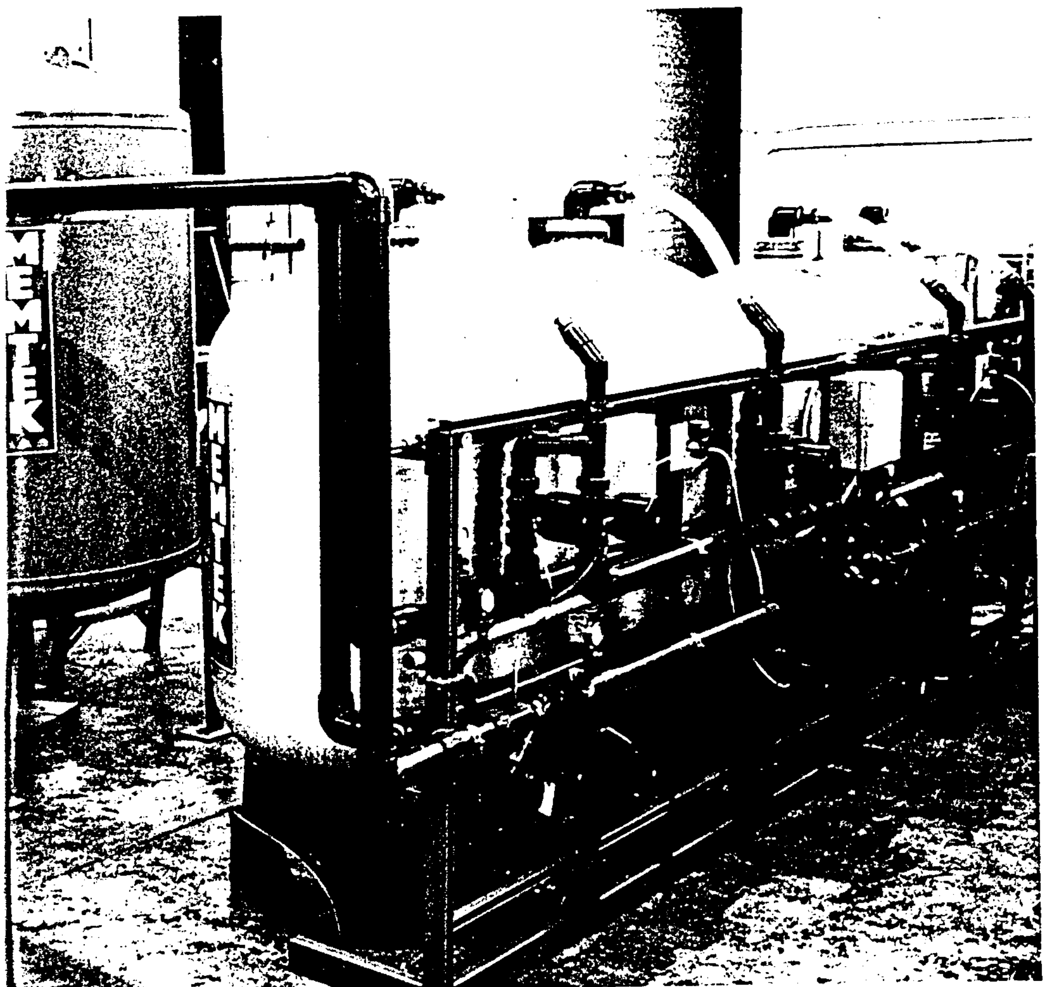
Based on actual data collected over a 6-month period at The Tingstol Company, Chicago, Illinois.

Consistently meets low discharge limits

The IX/ER® design with two columns in series, and regenerating as soon as the effluent from the primary column approaches the discharge limit, guarantees continuous environmental compliance.

Recycle capability

The IX/ER® can be followed by a deionizing or reverse osmosis unit to produce highly purified water for rinsing in a closed-loop system.



Handles concentrates as well as rinses

Addition of modular components to meter concentrates into the stream allows the IX/ER® system to process many waste streams, depending on the copper concentration.

Low operating costs

Regenerant solution is recycled. Plate-out power requirements are modest. Cathodes can be either reusable or disposable. Maintenance requirements are low.

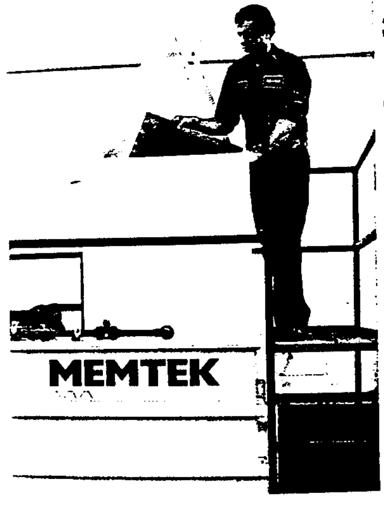
Liability - free disposal*

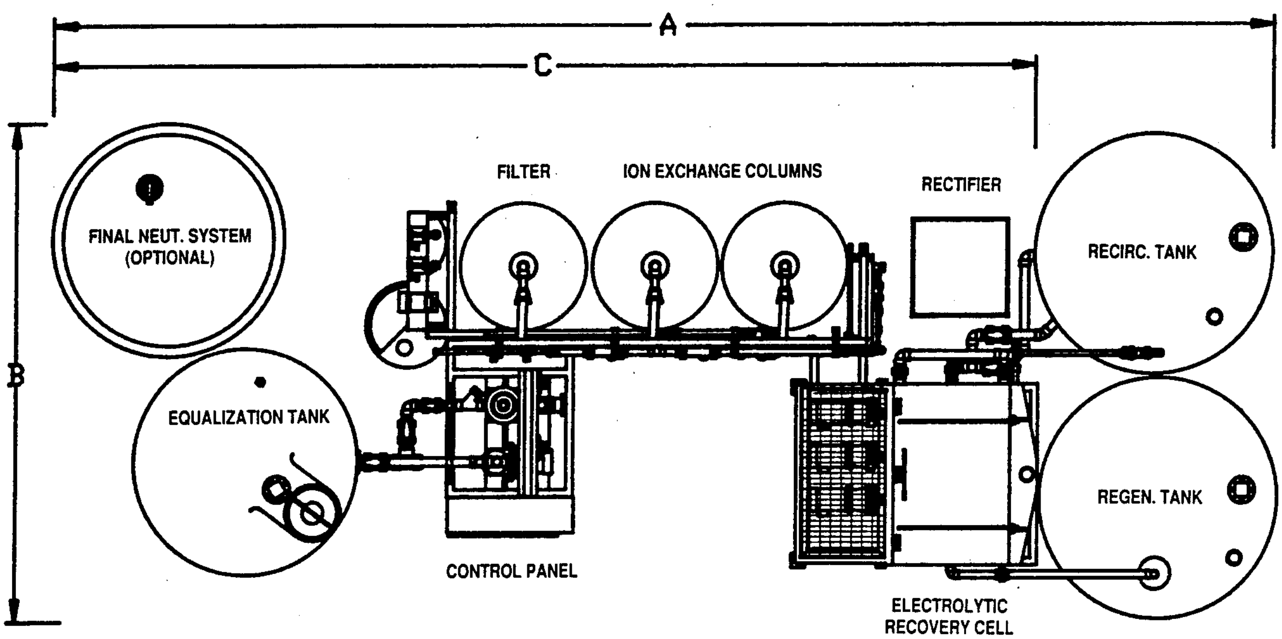
The IX/ER® reduces concern with sludge handling, hauling and disposal. Instead of a hazardous sludge, it produces copper sheets for disposal or sale.

* Based on experience in a number of locations. A check with the local regulatory agency is recommended to determine local requirements.

Performance you can count on

The IX/ER® system is backed by Memtek's reputation for reliability ... proven by hundreds of successful wastewater treatment installations throughout the world.





Note: Drawing shows larger system (40 - 100 gpm). Recirculation and regeneration tanks are located under the rectifier and electrolytic recovery cell on smaller systems (10 - 30 gpm).

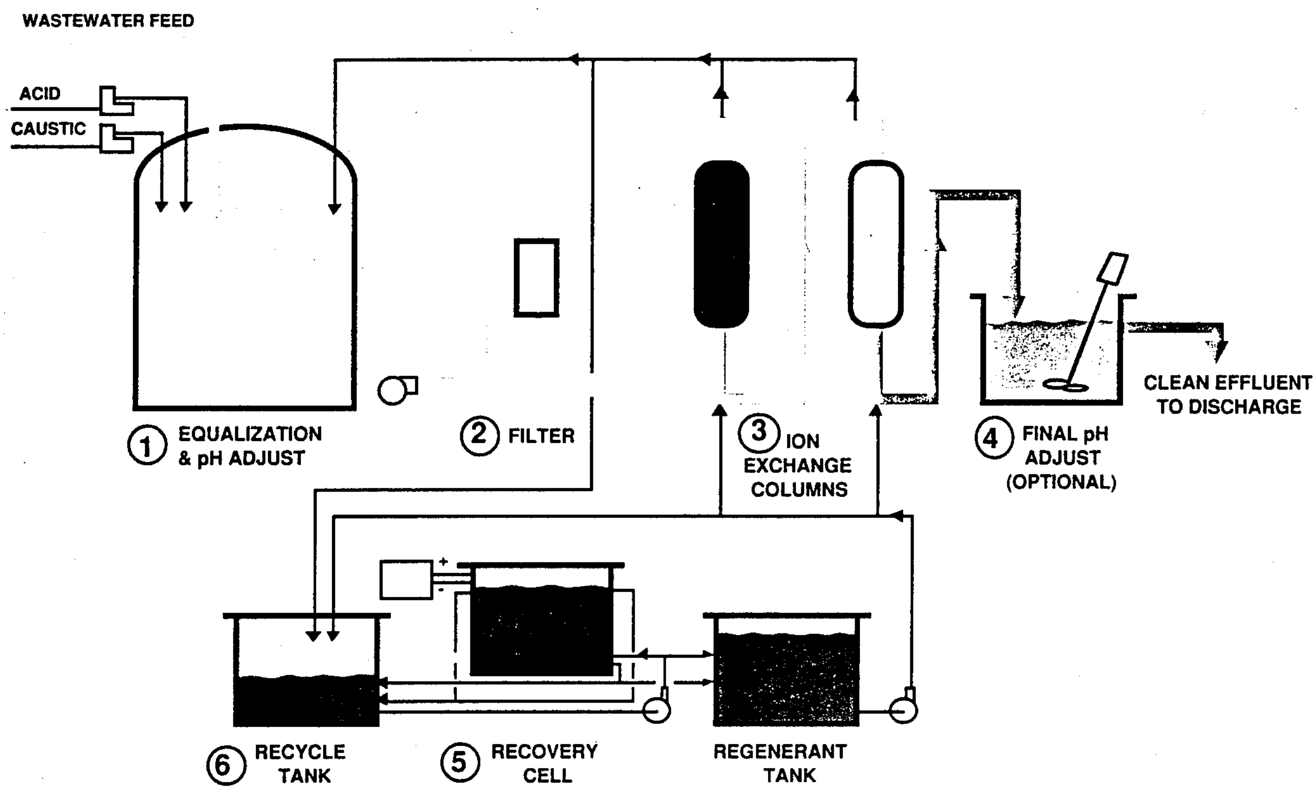
SPECIFICATIONS (Typical)*

SYSTEM DESIGNATION	IX/ER™	10/5	20/10	30/15	40/20	60/30	80/40	100/50
FLOW	gpm	10	20	30	40	60	80	100
METAL REMOVED	lbs./24 hrs.	5	10	15	20	30	40	50
ELECTRICAL	amps (460V)	30	35	40	45	60	80	100
RECTIFIER	amps	250	500	500	750	1,000	1,500	1,500
DIMENSIONS (ft.)	A Length	N/A	N/A	N/A	30'- 0"	31'- 5"	32'- 7"	34'- 0"
	C Length	21'- 3"	22'- 6"	22'- 6"	N/A	N/A	N/A	N/A
	B Width	9'- 2"	9'- 2"	9'- 2"	11'- 9"	13'- 7"	14'- 6"	15'- 2"
	Max. Height	9'- 7"	11'- 3"	11'- 8"	12'- 0"	8'- 9"	11'- 8"	12'- 7"
ION EXCHANGE COLUMNS	Dia. (in.)	16	24	30	36	42	48	48
FILTER	Dia. (in.)	21	24	30	36	42	48	30
TANK CAPACITIES (Gal.)								
EQUALIZATION		500	1,000	1,500	2,000	3,000	4,000	5,000
FINAL NEUTRALIZATION (optional)		200	300	500	750	750	1,000	1,500
RECIRCULATION		123	200	360	500	675	1,000	1,000
REGENERATION		123	200	360	500	675	1,000	1,000
PLATE-OUT CELL max. cathodes per cell		10	10	10	14	20	30	30

*The specifications shown illustrate typical sizes, weights, dimensions, and power requirements for IX/ER® units.
In practice, each MEMTEK IX/ER® system is designed to meet customer needs exactly, and specifications will vary accordingly.

FEATURES

- Microprocessor control
- Regenerant recycle
- Single step metal recovery
- Reusable cathodes
- Compact & skid-mounted
- Handles concentrates with ease
- Low maintenance
- Long-life resins
- Complete, turnkey systems
- Assured performance



SYSTEM OPERATION

1. Wastewater is first held in an equalization tank to smooth out fluctuations of metal concentrations. Concentrates, collected separately, are metered into the equalization tank. On larger systems, the wastewater flows to a pH adjustment tank for monitoring and pH adjustment to insure that the metals remain as dissolved ions. On smaller systems, pH adjustment takes place in the equalization tank.

2. Wastewater is filtered to remove insoluble debris.

3. Filtered wastewater is fed to ion exchange columns, operating in series, where selected resins remove metals to levels below discharge limits.

When the primary column is saturated to the extent that it no longer achieves the required degree of metal removal, this column is regenerated with acid, while wastewater is fed through the secondary column to maintain continuous treatment. After the primary column is regenerated, it is returned to service as the secondary column. The process is simple, semi-automatic, and microprocessor controlled.

4. The purified effluent from the ion exchange columns can be mixed with other wastewater or discharged after a final pH adjustment.

5. During regeneration, an acid solution removes the metal from the resin as dissolved ions and is fed to a plate-out cell where the metal is deposited electrolytically on stainless steel cathodes. When the metal reaches a thickness of 1/8"or more, it is stripped off as plates or sheets for disposal.

The metal plate-out process normally requires 16-20 hours in each daily cycle, and does not interfere with removal of toxic metals from the waste stream.

6. After the metal has been plated out, the regenerant is strengthened with fresh acid and recycled to serve in the next regeneration cycle.

Regular maintenance normally is limited to acid replenishment, filter replacement, and separation of metal sheets from the cathodes.

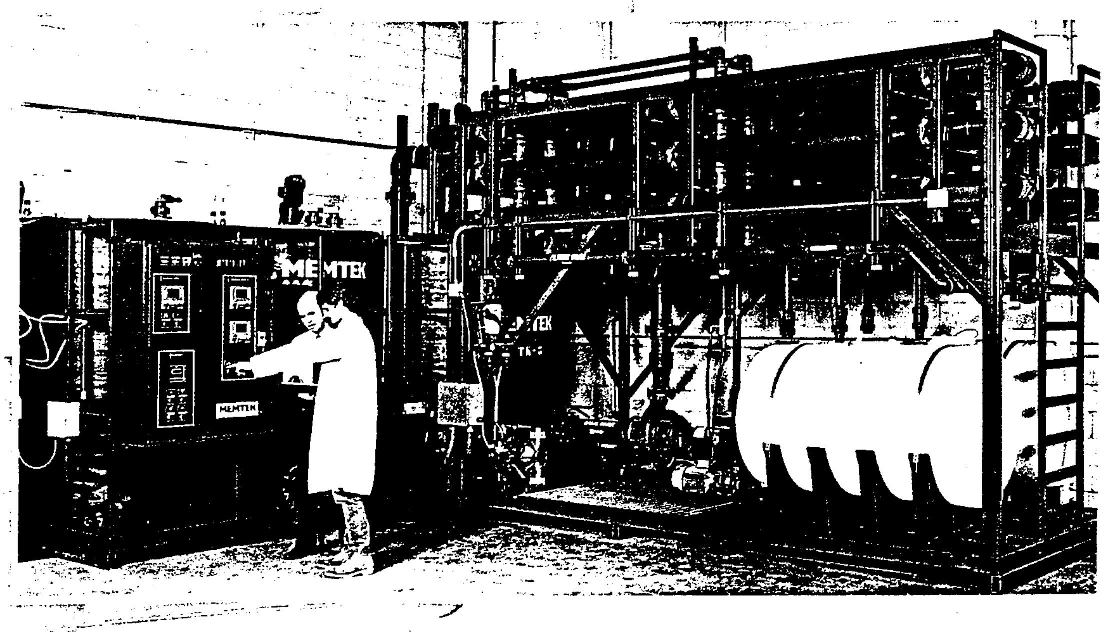
The only products released to the environment are clean water — well below the most stringent discharge limits — spent cartridge filters, and metallic plates suitable for disposal or sale.

MEMTEK

ADVANCED MEMBRANE FILTRATION WASTEWATER TREATMENT SYSTEMS

M-SERIES

SYSTEMS FOR GUARANTEED COMPLIANCE



WHY A MEMTEK M-SERIES SYSTEM IS YOUR BEST CHOICE

Guaranteed compliance...continuous, trouble-free removal of toxic contaminants...all with a complete, turnkey package

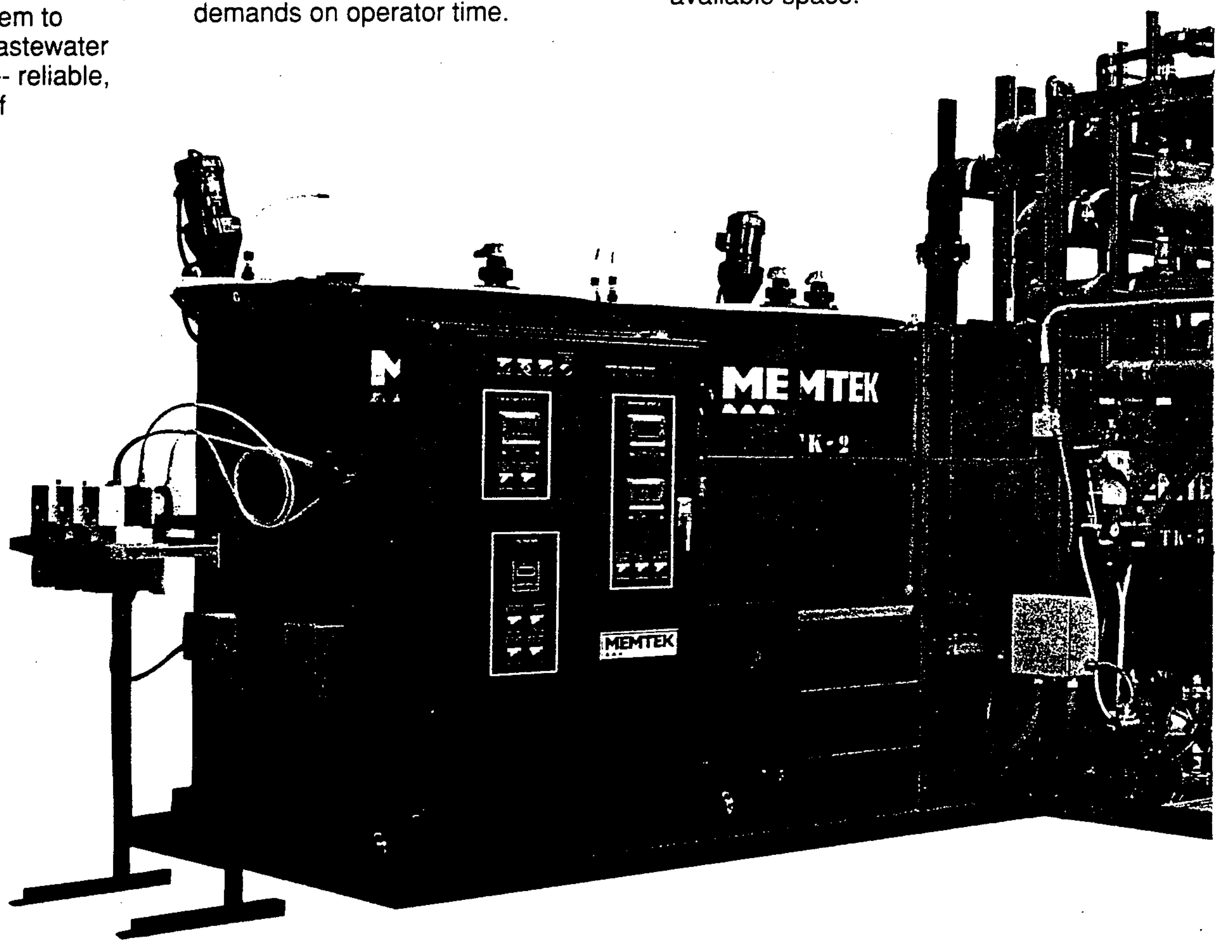
The Memtek Advanced Membrane Filtration Wastewater Treatment Systems offer a significant advantage over conventional precipitation and gravity settling processes -- an absolute barrier to the discharge of toxic contaminants. Memtek's proprietary membrane filter, of rugged design and extraordinary chemical resistance, coupled with appropriate chemical pretreatment, enable the Memtek system to deliver the ultimate in wastewater treatment performance -- reliable, continuous production of highest-quality effluent.

A complete system
Standard systems include all equipment and automatic controls for chemical pretreatment, membrane filtration, in-place membrane cleaning, and safety alarms

Simple operation
Memtek systems are designed for ease of operation and for continuous toxic materials removal without heavy demands on operator time.

Single-source responsibility
From design through installation, start-up, and training, you deal with a single supplier -- Memtek

Saves space... time...expense
Your Memtek system is factory-assembled for rapid installation at your site. The compact design offers several layout configurations to suit available space.



Complete installation & start-up
System installation, start-up assistance, and operator trainging are provided without extra cost.

Future flexiblity
Memtek can accommodate changes in wastewater characteristics by modifying chemical pretreatment. Generally, there's no need for additional equipment

AUXILIARY SYSTEMS

- Chromium Reduction
- Cyanide Destruction
- Waste Feed Systems
- Effluent pH Neutralization
- Concentrate Metering
- Powdered Chemical/Slurry
- Batch Treatment
- Solids Management
- Filtrate Transfer Station

Capacities for any requirement

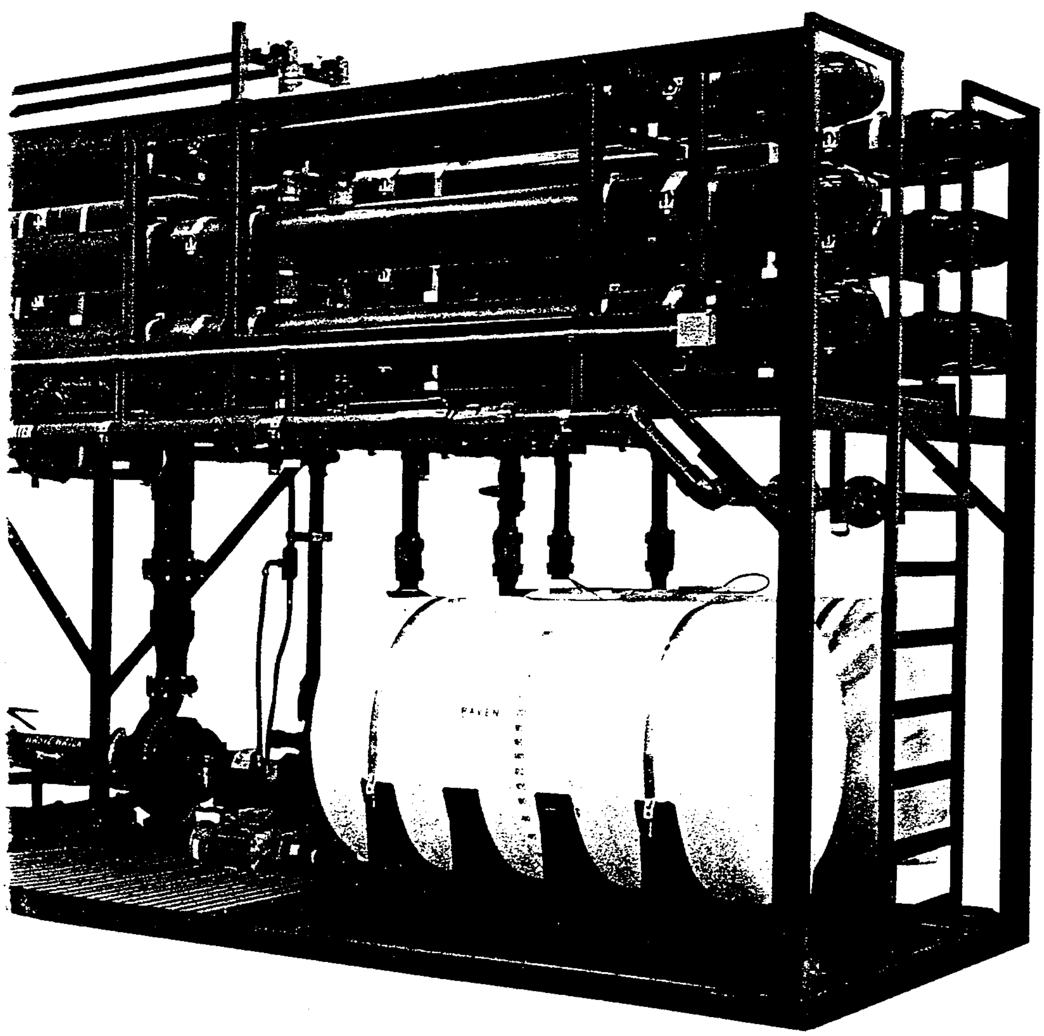
Standard Memtek systems cover a range of capacities from 6 to 150 gpm. Larger capacity systems -- with virtually no upper limit -- are available for special requirements. Modular construction simplifies expansion

Rugged, long-life membranes

The Memtek membranes are virtually indestructible. They are abrasion-resistant, non-clogging, and warranted for 5-years.

Long service life

Process tanks are fabricated from heavy-duty fiberglass reinforced epoxy resins. All components in contact with wastes are PVC, polypropylene, nylon, stainless steel, or other corrosion-resistant material.



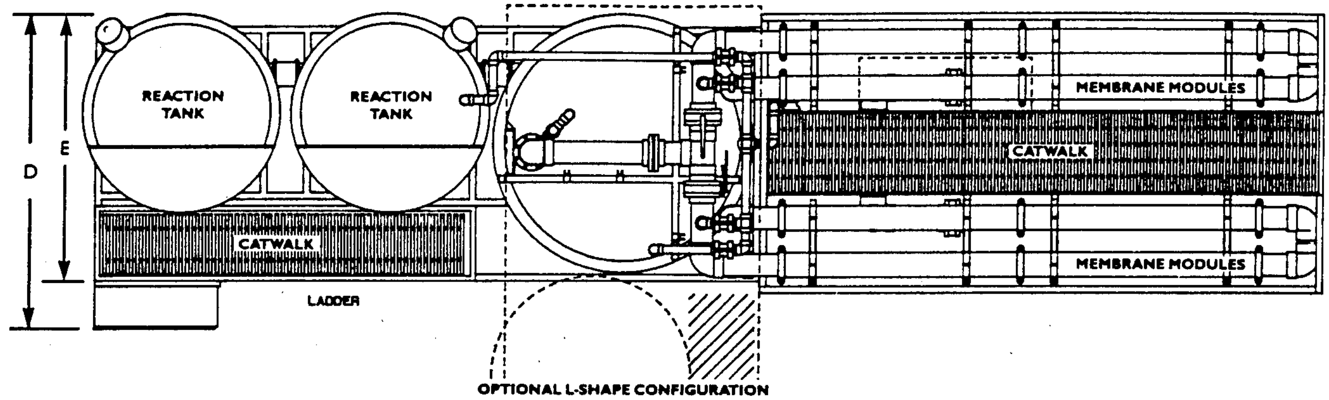
Performance you can count on --- *GUARANTEED*

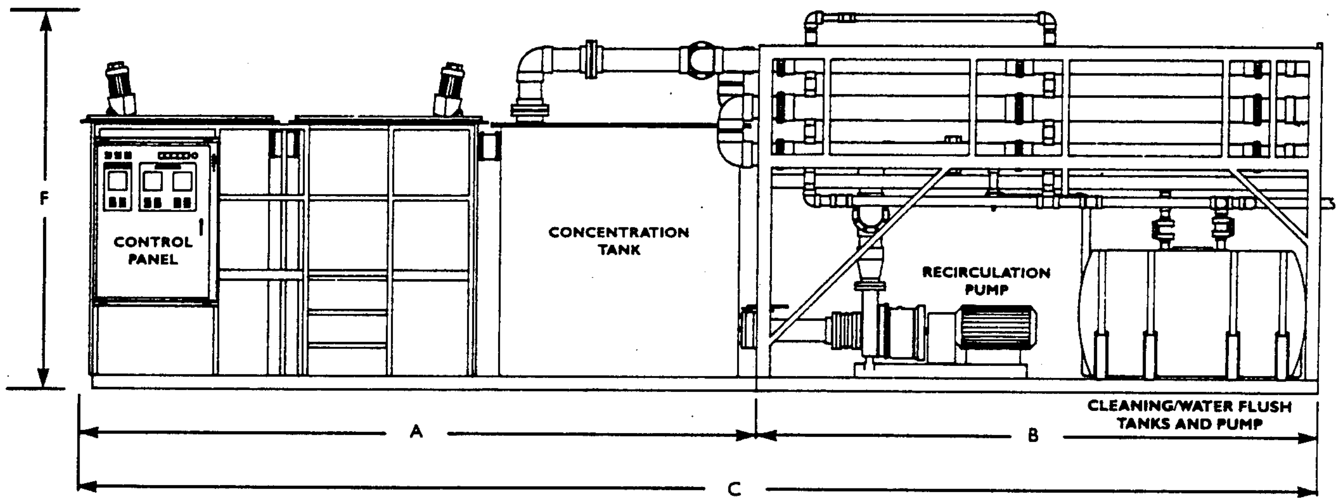
Every M-Series system carries the Memtek guarantee. Performance is guaranteed in writing to produce water that meets the required discharge limits for compliance with EPA and local regulations, based on treatability testing.

MEMTEK SYSTEM CAPABILITY

CONTAMINANT	WASTEWATER CONC. mg/l	MEMTEK EFFLUENT* mg/l
Aluminum	10 - 1000	0.5
Arsenic	1 - 50	0.05
Cadmium	25 - 115	0.05
Chromium	3 - 275	0.1
Copper	1 - 1500	0.1
Cyanide	5 - 300	0.1
Gallium	4 - 20	0.5
Germanium	20 - 110	0.5
Gold	1 - 12	0.15
Iron	2 - 1500	0.02
Lead	2 - 100	0.05
Manganese	1 - 10	0.02
Mercury	3 - 30	0.005
Nickel	4 - 300	0.1
Rhodium	20 - 500	0.1
Silver	10 - 200	0.1
Tin	20 - 75	0.1
Uranium	1 - 15	0.01
Zinc	2 - 400	0.1

* Typical values achieved in practice. Local values may vary depending on pretreatment chemistry





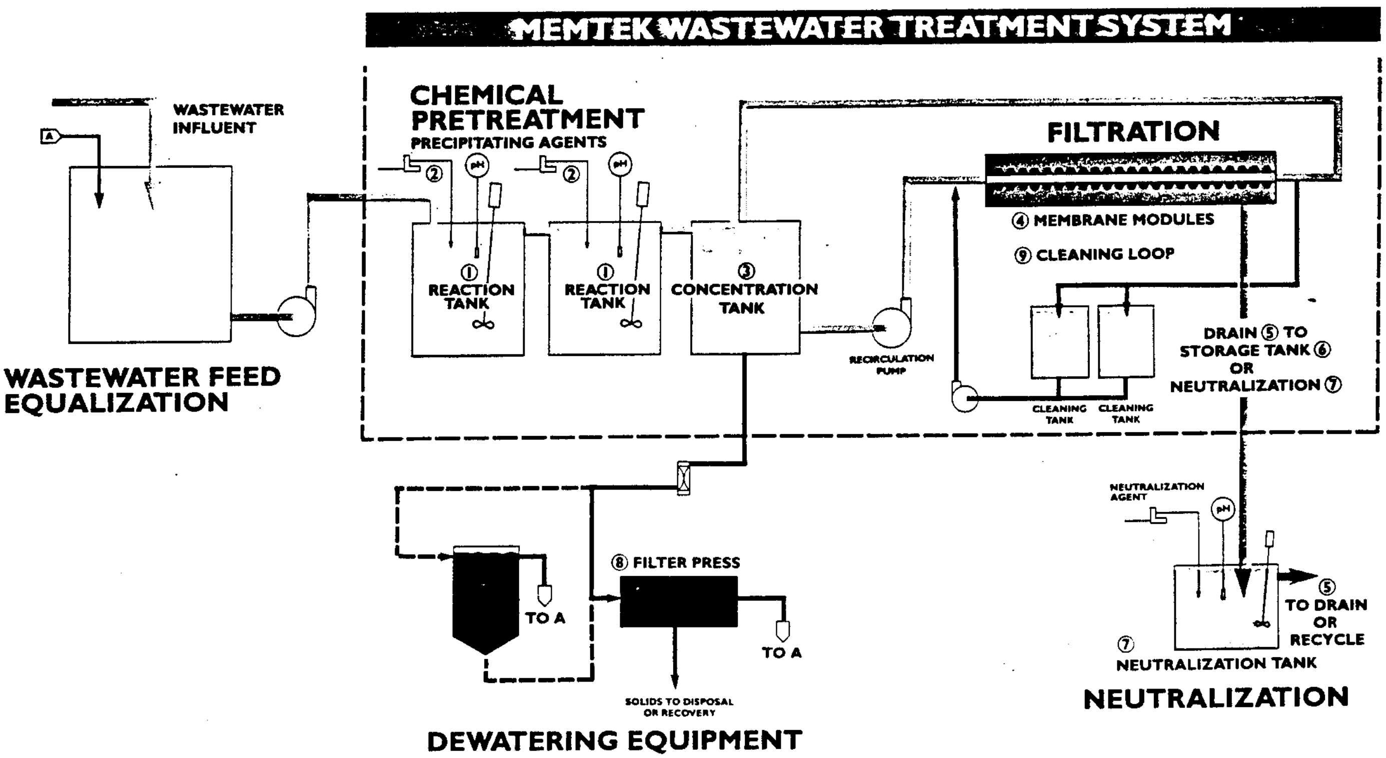
SPECIFICATIONS*

SYSTEM			M-400	M-1100	M-2200	M-3300	M-4400	M-6600	RS-1510	RS-2510
CAPACITY	gpm (nominal)		3-6	8-22	20-44	30-66	40-88	60-132	16-25	31-50
	Max gpd (24 hrs.)		8,640	31,600	63,400	95,100	126,800	190,100	36,000	72,000
MEMBRANE MODULES	Tubes/Module		4	10	10	10	10	10	10	10
	Number (min - max)		4-8	7-11	10-22	21-33	20-44	30-66	4-11	10-22
	Multiples		1	1	2	3	4	6	1	2
ELECTRICAL POWER (oper. kw)	Single Tank		6	16	23	31	46	62	N/A	N/A
	Double Tank		6.5	17	24	32	47	63	17	24
DIMENSIONS (ft - in)	Length Single Tank	A	N/A	N/A	12'-0"	14'-10"	18'-8"	22'-9"	N/A	N/A
		B	N/A	N/A	14'-2"	20'-10"	14'-2"	20'-1"	N/A	N/A
		C	18'-0"	24'-8"	26'-0"	32'-4"	35'-0"	41'-6"	N/A	N/A
	Length Double Tank	A	N/A	N/A	17'-4"	20'-1"	21'-6"	22'-9"	N/A	N/A
		B	N/A	N/A	14'-2"	20'-10"	14'-2"	20'-1"	N/A	N/A
		C	21'-0"	24'-8"	31'-0"	44'-8"	44'-0"	51'-0"	17'-0"	17'-8"
	Width	D	N/A	7'-9"	7'-8"	10'-5"	16'-0"	18'-6"	7'-4"	8'-6.5"
		E	N/A	7'-9"	7'-0"	10'-5"	16'-0"	15'-8"	6'-4"	8'-6.5"
	Height	F	8'-1"	10'-9"	10'-9"	10'-9"	12'-6"	12'-6"	9'-4"	13'-4"
WEIGHT (lbs.)	Single Tank	Wet	7,000	23,000	27,000	41,000	53,000	71,000	N/A	N/A
		Dry	2,700	8,000	9,000	12,000	15,000	22,000	N/A	N/A
	Double Tank	Wet	15,000	26,000	33,000	50,000	63,000	87,000	26,000	26,000
		Dry	7,000	8,000	9,000	13,000	15,000	22,000	8,000	13,000

*specifications subject to change without notice

FEATURES

- Guaranteed compliance with EPA and local discharge limits
- Complete, turnkey systems
- Compact & skid-mounted
- Simple, trouble-free operation
- Low maintenance
- Capacities from 6 - 600 gpm, and higher
- Consistent metals removal to 0.1 ppm or less -- as low as 0.02 ppm



SYSTEM OPERATION

The process begins with transfer of wastewater to one or more reaction tanks (1) followed by controlled addition of pretreatment chemicals to precipitate the toxic contaminants to filterable particles. (2) The most economical pretreatment chemistry is selected depending on the nature of the wastewater, the contaminant removal efficiency desired, and keeping the solids volume to a minimum. Reactions are monitored and controlled automatically and continuously.

The chemically pretreated wastewater then flows to the concentration tank (3) and is pumped continuously through the tubular membrane filtration modules (4) at a high fluid velocity. At the normal operating pressure (20 - 40 psi), clean water is forced through the pores of the membrane while the particulate contaminants remained suspended in the recirculated stream. The turbulence of the recirculated slurry prevents the contaminants from accumulating on the membrane surface, and thereby maintains high and continuous filtration rates.

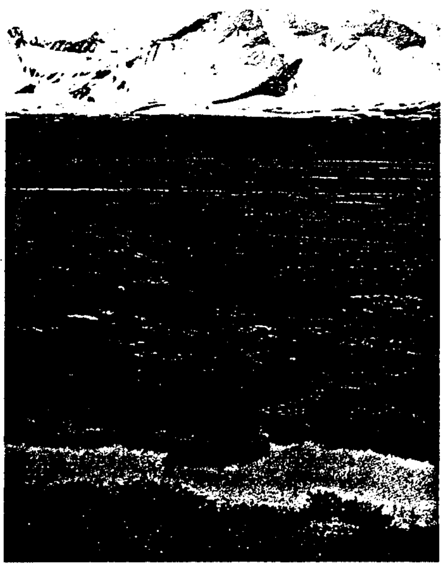
The clean water flows by gravity from the membrane modules to a drain (5), storage tank (6), or the final neutralization tank (7). Clean, neutralized filtrate can often be used as recycle water for non-critical rinses.

The concentration of the wastewater slurry recirculated in the membrane modules is maintained at 2 - 5% solids. Under normal operating conditions, a portion of the slurry is periodically removed from the system, usually to a filter press (8) which produces a dry (30 - 40% solids) cake for disposal. Filtrate from the press is returned for reprocessing.

Only clean water leaves the system through the membrane modules.

Every Memtek system includes a convenient integral cleaning loop (9) consisting of a pump, tanks, and the necessary piping and valving to permit in-place cleaning of the membrane modules. No disassembly is required. Cleaning normally requires less than two hours, after 60 - 100 hours of operation.

a clear vision for a cleaner world



Environomics introduces a revolutionary system that applies physical chemical principles to treat wastewater streams contaminated with heavy metals, oils, greases and suspended solids — leaving no hazardous waste residue!

Electrofloc™ is a field-tested, proven process that treats heavy metals by transforming them chemically — at the molecular level — into harmless substances. It takes contaminated liquids in one end and discharges clean water and harmless sludge out the other.

You can recycle the water or dispose of it directly into your local sewer. The remaining solid residue meets all EPA standards for disposal in a sanitary landfill, eliminating the need for high-cost disposal at a hazardous waste site. Because no hazardous wastes are produced, you will not face the "cradle to grave" responsibility of tracking and owning hazardous wastes forever.

System [illegible]

Environomics produces Electrofloc™ process modules that will meet your flow and contaminant reduction requirements dictated by federal, state and local laws. We will perform treatability studies, help you obtain permits and prepare the installation site for electrical and plumbing hookups. We'll also install and test the equipment, train your operators and provide thorough operating and maintenance instructions. If you want assistance down the line, we will respond immediately to your need.

Our modular installation can handle from a few thousand to more than 250,000 gallons per day. Electrofloc™ reduces high concentrations of oil, grease and total suspended solids — from thousands of parts per million (ppm) to less than 20 ppm. The process also reduces heavy metals to parts per billion levels that meet current and future EPA standards.

Environomics will perform a feasibility study on an actual sample of waste from your facility. This will allow us to verify the treatability of your waste stream, and provide you with accurate data on the expected results, capital and operating and maintenance costs.

environomics

Electrofloc™ is suitable for a wide range of applications where a combination of oil, grease, heavy metals and suspended solids are present, such as:

- Automotive repair facilities
- Electronics and semiconductor manufacturing
- Industrial laundries
- Manufacturing
- Marine maintenance facilities
- Mining
- Paint and chemical industry
- Petroleum and petrochemical industries
- Truck and car washes

- Essentially eliminates heavy metals from wastewater
- Greatly reduces oil, grease and suspended solids
- Leaves no hazardous waste stream
- Applicable over a wide range of contaminants
- Treated water can be recycled
- Comprehensive controls with remote alarms
- Solids eligible for sanitary landfill
- Meets or exceeds EPA contaminant limits
- Low installation, operating and maintenance costs
- Simple to operate
- 24-hour service response from Environomics
- Modular design — adaptable to your facility
- Operator training provided
- Warranty

Ignitablility — Pass

Corrosivity — Pass

Reactivity — Pass

	Actual	Limit
Lead	<.1	5.0
Cadmium	<.01	1.0

Total Suspended Solids	2,000 ppm	3,500	<20 ppm
Oil/Grease	2,500 ppm	5,500	<20 ppm
Heavy Metals	20 ppm	30	<10 ppb

$M^{+} + (O^{-2}, OH^{-}) \rightarrow M^{+,++,+++}(O^{-})(OH^{-})$

Oils, Grease (O/G) $+ (O^{-2}) \rightarrow C_xH_y(OH)_z$

+ Polymers, Inorganic Coagulants

$M^{+,++,+++}(O^{-})(OH^{-}) \downarrow$

O/G $\downarrow$

T.S.S. $\downarrow$

The filtered sludge and proprietary reagent yields:

- Sludge disposable to any sanitary landfill
- Non-leachable by TCLP and California leach tests

The name Electrofloc™ comes from the process of electroflocculation, which is used simultaneously with chemical flocculation to optimize system performance. Electrofloc™ effectively and dramatically reduces the levels of heavy metals, oil and grease and suspended solids in contaminated water. The contaminants in the resulting sludge-cake are chemically fixed to prevent leaching and meet stringent EPA requirements.

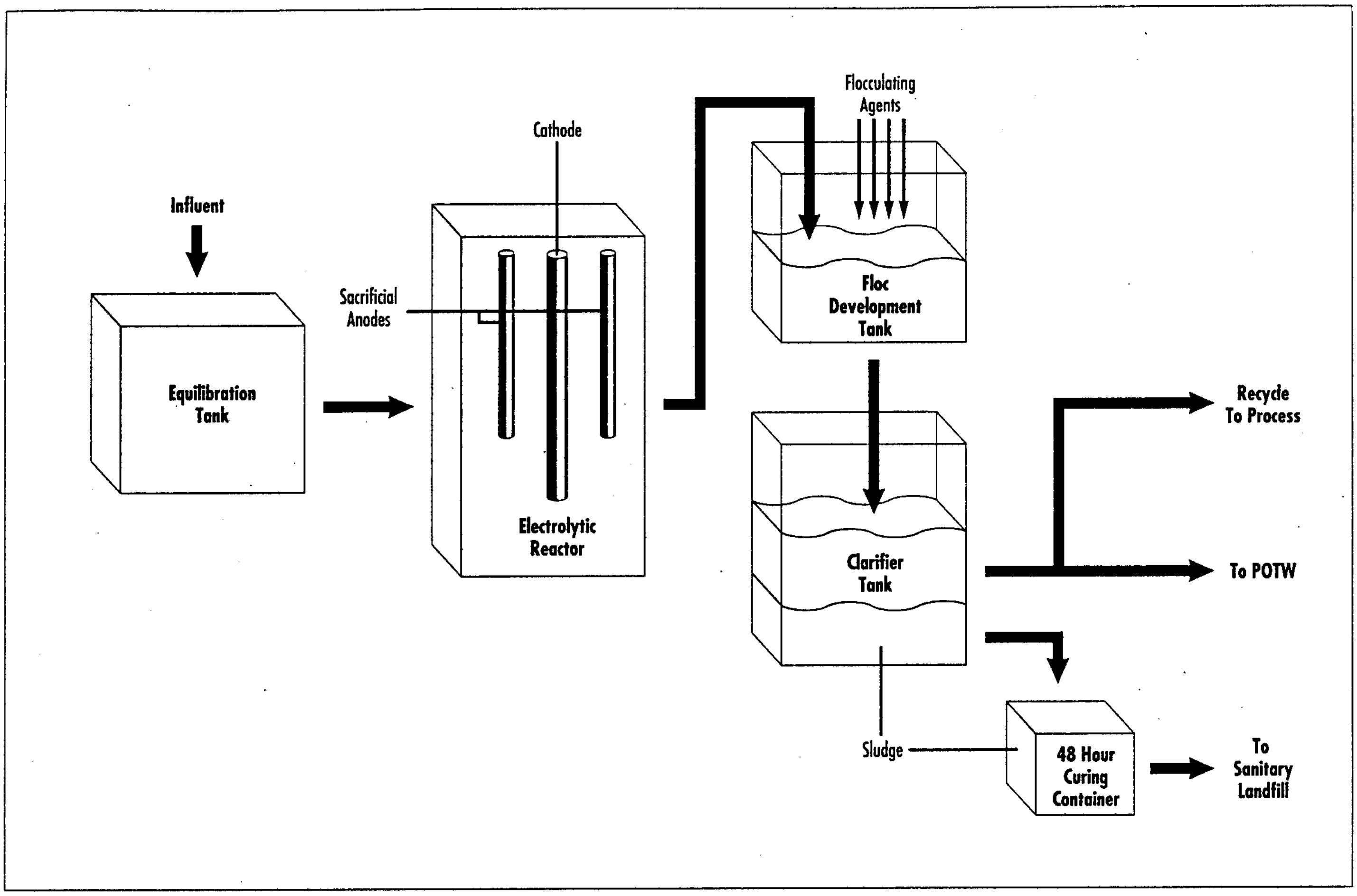
Although the net effect of electroflocculation is similar to chemical flocculation, the process enhances insolubility and bonding. These features play an extremely important role in the Electrofloc™ system's ability to attain very low levels of contaminants.

The electroflocculation process occurs in modular chemical reactors, each capable of a flow rate of 12.5 GPM. The key elements of these reactors are sacrificial anodes, which tenaciously bind the heavy metals, and partially oxidize the oils, greases and VOCs, resulting in a purer effluent.

The net chemical effect is the production of metal oxy-hydroxides of the contaminant molecules, which are absorbed preferentially by the nascent sacrificial anode hydroxides to produce a low solubility precipitate. This allows the Electrofloc™ system to reduce contaminants to very low concentrations.

Flocculating agents automatically enter a mixing tank. The process stream later runs through a clarifier tank, where the resulting sludge precipitates. The clean water then recycles back to the process or to a POTW outlet, as required.

The sludge travels to a final tank where a unique rotary vacuum filter introduces a controlled amount of chemical fixation catalyst, and directs the treated sludge-cake into a suitable container. A 48-hour curing period renders the sludge to a hardened mass that can be disposed into a sanitary landfill, as it is chemically fixed per EPA standards.



The influent waste water stream preferably collects in an appropriately sized buffer or equalization tank. Because of the wide range of contaminant types and concentrations, this tank is used to even out the characteristics of the flow for a smooth and continuous operation.

The wastewater is pumped from the buffer tank into a parallel bank of cylindrical reactors where the electroflocculation process occurs. Each module contains a corrosion-resistant cathode and a set of proprietary sacrificial anodes.

Each module can handle a flow rate of 12.5 GPM. You can increase the capacity of this modular system simply by adding more units to meet your flow requirement. The capacities of other tanks in the system are designed to allow for the appropriate residence times in each stage.

The reactors produce low solubility precipitates, which are carried by gravity flow into a mixing tank, where they are chemically augmented by flocculating agents for easy phase separation. These agents are fed at an automatically controlled rate.

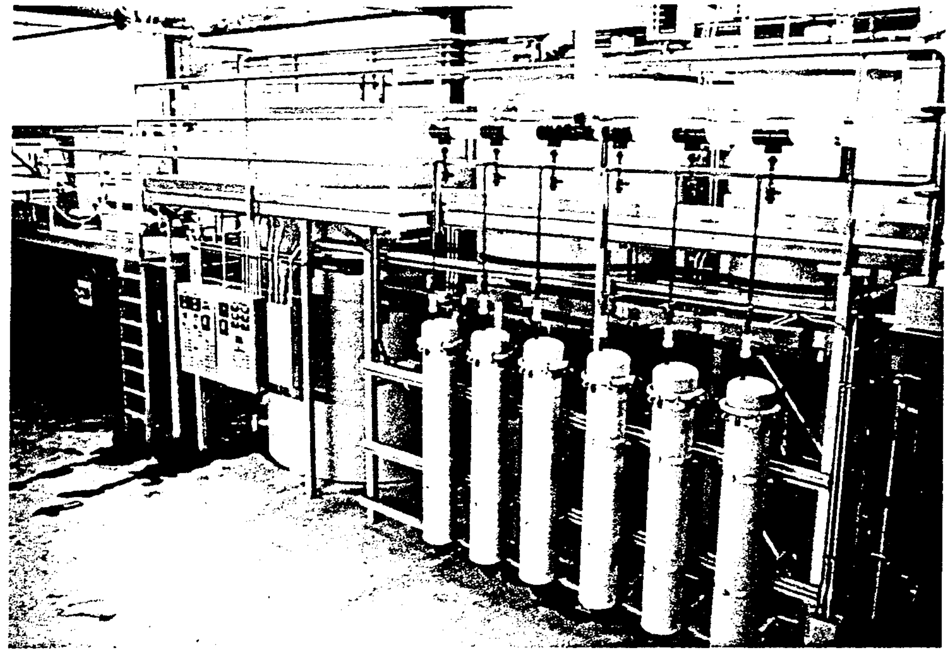
The clarifier tank separates the treated water and the flocculated sludge. When the separated floc reaches a preset quantity, the sludge travels to another tank where a rotary vacuum filter finalizes the separation of sludge and treated water.

The leachability resistance, initially developed in the electroflocculation stage, is augmented in the chemical fixation stage and finalized just after the rotary vacuum filter stage. In this last step, the sludge mixes thoroughly with chemical fixation agents and then cures at room temperature for 48 hours.

The resulting cake is a hardened material that breaks into manageable sized pieces when dumped into a transport container. After 48 hours, the chemically fixed material will pass the toxic leachability tests of the EPA and is ready for disposal into a sanitary landfill.

The system is microprocessor-controlled and instrumented for critical parameters such as influent and effluent pH levels, electroflocculation voltages and currents, liquid levels, etc. Indicator lights pinpoint system performance for easy maintenance and smooth operation. Remote alarms are available for one or more locations, thus eliminating the necessity for full-time operator assistance. This keeps labor costs at a minimum.

The system shown here has a flow capacity of 72.5 GPM. In top photo, the footprint of 10' by 40' is located over a 25,000 gallon buffer under the floor. The cylindrical reactor modules are clearly visible. Water is pumped through these units to the treatment tanks above, and the rest of the system operates on gravity feed.

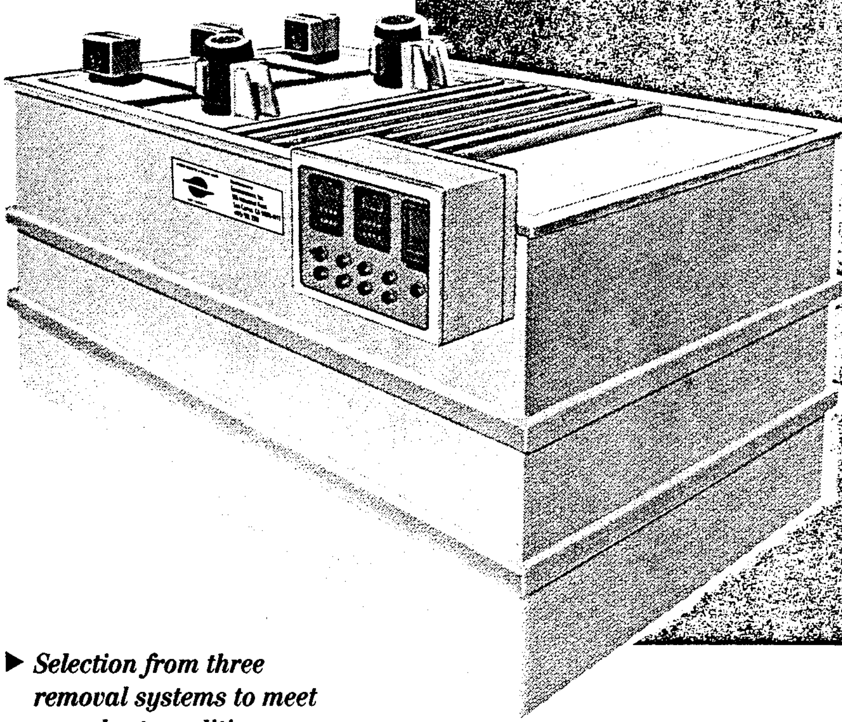


On the upper deck, pictured at right, the mixing tank is visible in the front, with the floc development tank and the clarifier tank located behind it. The final filtering and chemical fixation stage occurs at the back of these tanks. The sludge falls down into a collecting container located on the ground level, as seen at the rear in the top photo.

Wastewater treatment equipment *from*

environomics

CHEM-PURE DIVISION



Heavy Metal and HF Removal Systems

For removal of heavy metals from wastewater and flourides from hydroflouric acid to meet federal, state, and local discharge regulations.

- ***Selection from three removal systems to meet any plant condition***
- ***Polishing of clarified water to improve effluent quality to .001 ppm***
- ***Fully-automatic, microprocessor-based control system***
- ***Low-level sensors and alarms***
- ***Metal recovery package***
- ***Reagent tanks built-in or external***
- ***Unitized construction for small footprint***
- ***Easy installation***

Metal Removal System Model EMC
with optional Enviro Filter Model EMF, Ion Exchange Package Model EMX, and Compact Clarifier Model EC. HF Treatment System Model EHF.

Chem-Pure offers compact treatment systems designed to remove heavy metals and neutralize the wastewater to meet federal, state, and local regulations. We offer three different design concepts to meet specific treatment needs.

For plants developing high flow rates and a high concentrations of heavy metals, we recommend our compact clarifier to settle out metals after chemical treatment. A filter press or large Enviro Filters can be incorporated for sludge dewatering.

For plants having flow rates under 20 gpm and metals concentrations in the medium- to low-ppm range (under 500 ppm), we recommend chemical treatment followed by our Enviro Filters to remove the metals. Enviro Filters not only remove the metals, but also dewater the metal hydroxide sludge that is trapped in the filter. This filter package produces effluent to .05 ppm, which is well under the limits throughout the U.S. for discharge or reuse in the plant.

For plants, laboratories, R&D facilities, and startup companies that develop low volumes of wastewater and have low concentrations of metals, we offer our Ion Exchange system. This technology produces the best quality of effluent (.001 ppm).

▶

HEAVY METAL REMOVAL FROM WASTEWATER

Flow (GPM)	Heavy Metals Concentration	Treatment Equipment	Effluent Quality
1-20	Under 500 ppm	Enviro Filters Ion Exchange	.05 ppm .001 ppm
1-20	Over 500 ppm	Compact Clarifier Enviro Filters	0.5 ppm .05 ppm
21-100	High	Compact Clarifier	0.5 ppm

Polished Effluent

Enviro Filters and Ion Exchange Packages can also be used to polish clear water coming off the Clarifier. This will improve the effluent quality to .05 ppm for the Enviro Filters and .001 ppm for the Ion Exchange Package. Since the clarified water is already of excellent quality, the Enviro Filters and Ion Exchange Package can operate for long periods before replacement.

POLISH WASTEWATER FROM COMPACT CLARIFIER

Treatment Equipment	Effluent Quality
Enviro Filters	.05 ppm
Ion Exchange	.001 ppm

HF Removal Systems

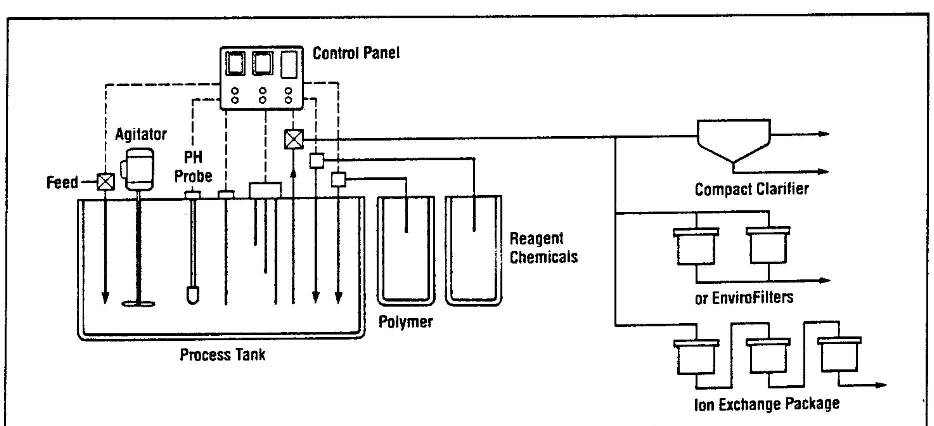
In treating HF to remove flourides, we offer a Compact Clarifier following chemical pre-treatment for plants producing large volumes of HF having high concentrations of flourides.

We also offer our Enviro Filter for those facilities that produce low- to medium-volumes of HF. The filter can meet an effluent quality of .05 ppm, while dewatering the sludge for ease of disposal. Sludge dewatering is handled by our air blowdown system, which extracts additional moisture to prepare the spent filter bag for disposal.

We can provide a metal plating package for customers who generate a single metal. This offers a closed loop system where the metal can be recovered for reuse.

FLOURIDE REMOVAL FROM HF

Flow (GPM)	Flouride Concentration	Treatment Equipment	Effluent Quality
1-100	Any	Compact Clarifier	0.5 ppm
1-20	500 ppm	Enviro Filters	.05 ppm



▲ *Typical System Block Diagram*

Control Systems

All instruments are microprocessor-based for accuracy, reliability, and ease of calibration. Our systems are fully automatic from plant influent to treated effluent. We can also offer a programmable logic controller with built-in computer, if desired.

Options

A wide range of accessory equipment, such as pump stations, oil and grease removal equipment, cyanide and other organic chemical destruction equipment, and skid-mounted packages, are available to complete a wastewater treatment system.

Construction

A single compartmented vessel is supplied, constructed of polypropylene and reinforced with steel ribs. Reagent chemical tanks and secondary containment tanks can be supplied to meet all regulations.

Easy Installation

Chem-Pure systems ship completely self contained. All that is required to complete the installation is to connect power to the control panel and plumbing to the inlet and outlet.

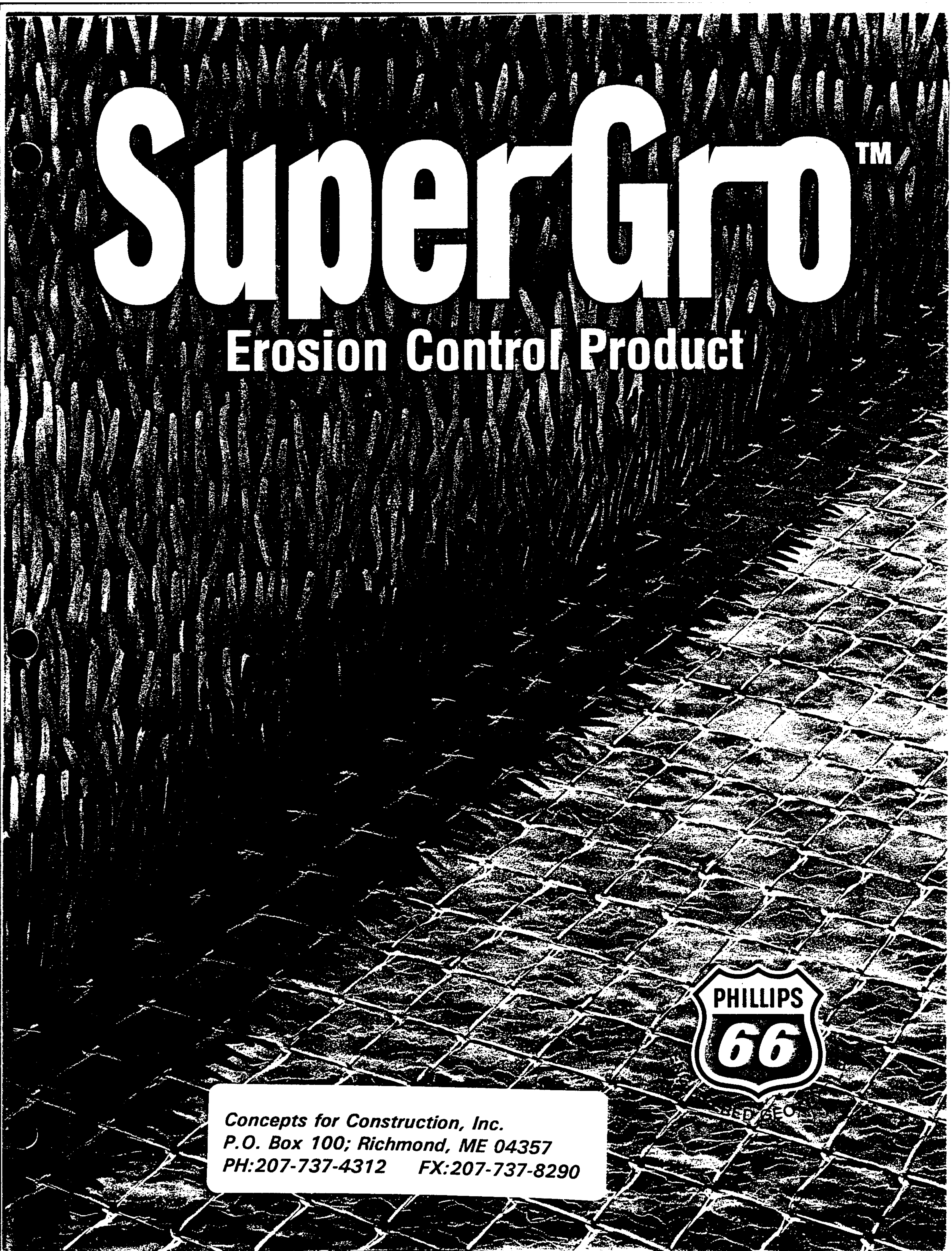
Other Environomics Products

- *Chem-Pure pH Neutralization Systems*
- *ELECTROFLOC™ heavy metal, oil, grease, and suspended solids removal*
- *RADINOX™ VOC destruction systems*
- *Solvent recovery and recycling system for rags, wipes, and gloves*
- *AquaMore hot water reuse system for commercial laundries*
- *Treatment systems for vehicle washing—trucks, autos, buses, trains, aircraft*
- *Plant washdown systems to remove oil, grease, solids, and chemicals*

ENVIRONOMICS, INC. 955 Industrial Road, San Carlos, CA 94070-4117 ■ Phone 415-592-2552 ■ Fax 415-592-1543

SuperGro™

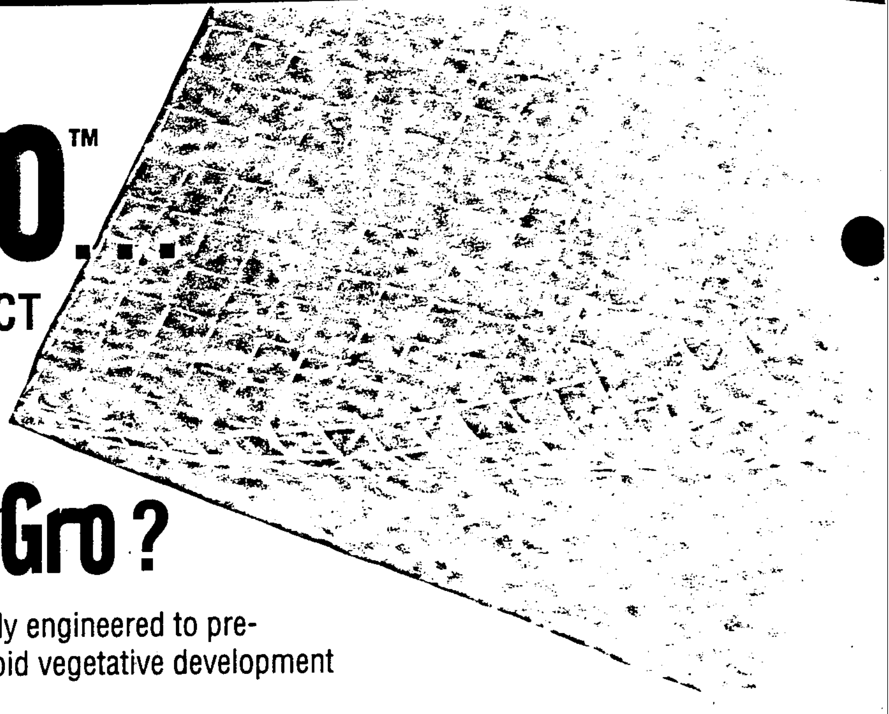
Erosion Control Product



Concepts for Construction, Inc.
P.O. Box 100; Richmond, ME 04357
PH:207-737-4312 FX:207-737-8290

SuperGro™...

EROSION CONTROL PRODUCT



What is SuperGro?

A unique product, SuperGro is specifically engineered to prevent surface erosion while promoting rapid vegetative development on freshly landscaped areas.

A flexible composite, SuperGro consists of a nonwoven polypropylene fiber blanket reinforced with polypropylene netting.

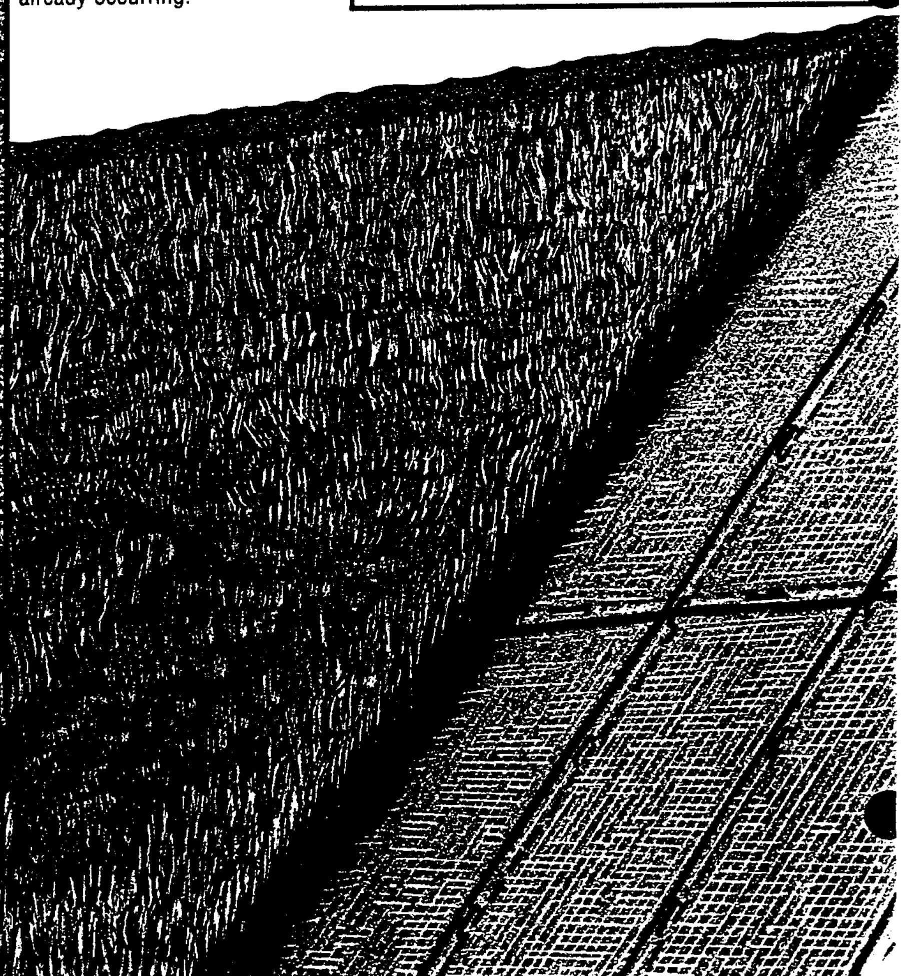
Availability and Packaging

SuperGro is wound on a disposable paper core and protected by a polyethylene film wrap. It is available as follows:

Width	48" or 96"
Weight	23 lbs. or 45 lbs.
Length	250 lin. yds.

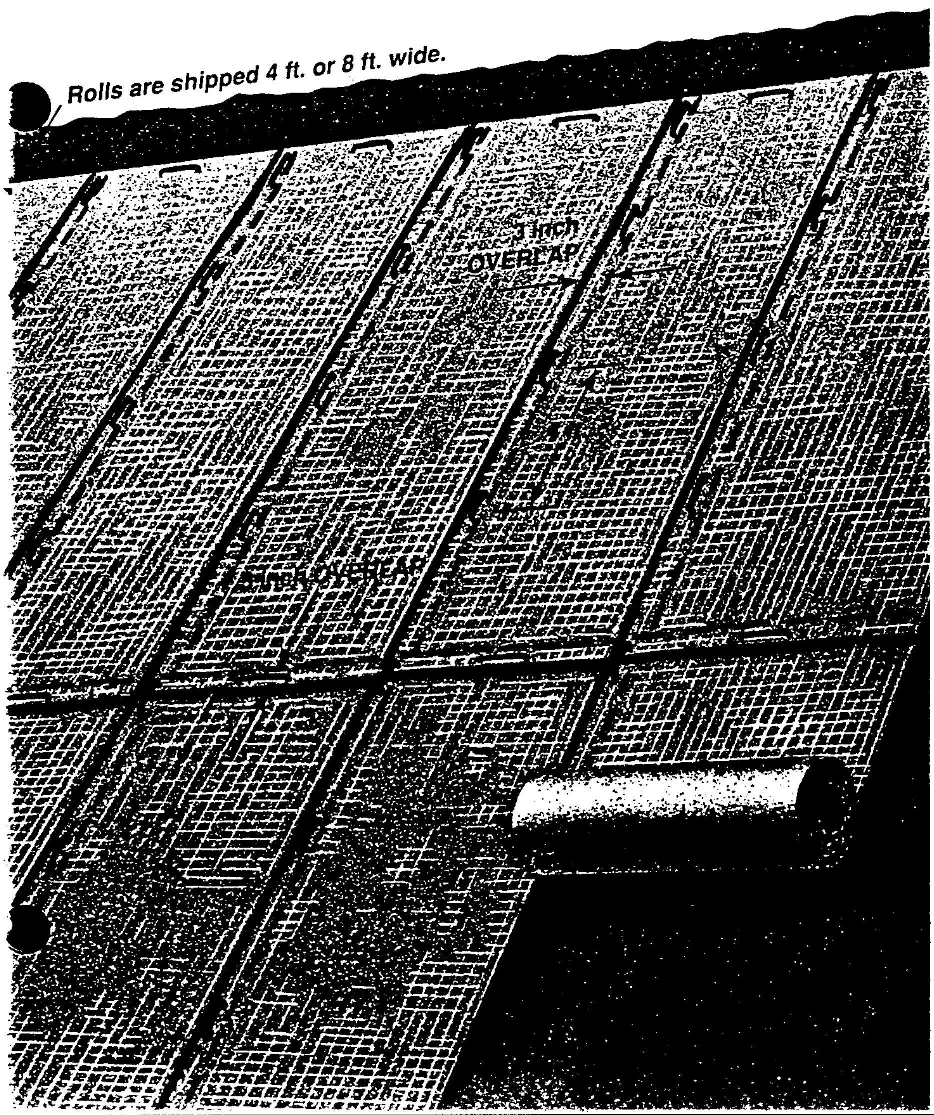
There are approximately 333 and 666 square yards of fabric on each roll. Other lengths and widths are available by special order.

Conventional seeding. Heavy erosion is already occurring.



What are the advantages of SuperGro?

- Grass seed is secured in place.
- Moisture is retained for seed germination.
- Provides fiber reinforcement to erodible soils.
- Water, air and sunlight are allowed to penetrate.
- SuperGro™ meets flammability test CS191-53, consequently is much safer than straw, wood shavings and paper products which are easily ignited.
- The environment is not harmed. SuperGro is ultra-violet degradable.
- Chemically inert.
- Much cleaner system compared to hay, straw, and spray-type systems.
- Lightweight SuperGro is easier to transport, handle, and install, than any other erosion control system.
- Vegetative sprigs are easily planted through SuperGro.



What are the end-uses for SuperGro?

SuperGro is a versatile, economical product which has numerous applications in landscaping and erosion control for:

- highways
- railroads
- construction sites
- mining and mining reclamations
- forest and reforestation
- recreation and parks
- airfields
- oil fields
- irrigation systems
- landfills
- beach and dune erosion stabilization

SuperGro is simple to install.

1. Prepare the ground surface either by mechanical means and/or raking to as smooth a surface as is practical.
2. Seed and fertilize the area.
3. Unroll SuperGro mat with the netting side on top. **Note:** Do not stretch the product. Make sure the mat is relaxed on the surface.
4. Anchor the mat by placing the pins at 4 ft. ± 1 ft. intervals in adjacent panel overlap area. When using 8 ft. wide rolls, pin down the adjacent panel overlaps and the center of the mat at 4 ft. intervals. Overall anchoring should be approximately 4 ft. on center. **Note:** Be sure the pins are well-secured in the ground. Use 4-6" U-shaped pins, depending on the condition of the ground. Pins can be pressed into the ground either by hand or using a small hammer. Wood pegs may be used if preferred.
5. Overlap the end of each roll and adjacent panel sides at least 3 inches. Overlap by "shingling" in the direction of the water flow.
6. Anchor the top, bottom and any end of roll overlaps.
7. Water lightly, after installation if possible; this will enhance grass growth and interlock the fibers into the soil.

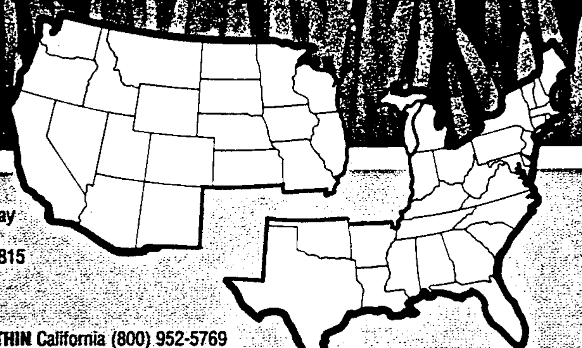
Phillips Fibers Corporation, manufacturer and supplier of SuperGro™, is headquartered in Greenville, South Carolina. Formed in 1966, it is a subsidiary of Phillips 66 Company.

SuperGro is manufactured in Phillips' Seneca, South Carolina plant. Marketing, engineering, and technical assistance are available at two zone offices. These are located in Sacramento, California, and Greenville, South Carolina. Phillips sales representatives and distributors are located throughout the United States to provide quick and reliable service.

Look to Phillips Fibers for performance.

PHILLIPS 66

ENGINEERED GEOTEXTILES



FOR INFORMATION CALL
Within Eastern Zone, except South Carolina
(800) 845-5737, 8AM-5PM Eastern Time.
Within Western Zone, except Alaska, California and Hawaii
(800) 437-6600. 8AM-5PM Western Time.

WESTERN ZONE
1900 Point West Way
Suite 261
Sacramento, CA 95815
(916) 924-3151

WITHIN California (800) 952-5769

EASTERN ZONE
Box 66
Greenville, SC 29602
(803) 242-6600
WITHIN South Carolina

PHILLIPS FIBERS CORPORATION • P.O. Box 66 • Greenville, SC 29602 • (803) 242-6600

8640-3RBR

ABB
ASEA BROWN BOVERI

ABB Environmental Services, Inc.
110 Free Street
P.O. Box 7050
Portland, Maine 04112-7050
Telephone (207) 775-5400
Fax (207) 772-4762

TELEPHONE MEMORANDUM

PROJECT NO.: 6853-09 DATE: 5-20-93

CLIENT: BADGER FS

PROJECT DESCRIPTION:

BETWEEN: JEFF ROSENBLUM

AND: MATT SMITH, 737-4312

SUBJECT: EROSION CONTROL FABRIC

Supergrow (TM) by Philips Fibers Corp. is recommended for the Main Ditch. Come in rolls 4' & 8' wide, 666 feet long.

Expected cost ~ $0.50 per yd^3

Installation ~ $1.50 per yd^3.

DISTRIBUTION:
ABB

GEO•CON® INC.
GEOTECHNICAL CONTRACTING

June 24, 1994

Mr. Philip R. Martin, P.E.
ABB Environmental Services Inc.
110 Free Street
Portland, ME 04112

3045

Re: Soil Stabilization

Dear Phil:

I have received the information that you had faxed to my office on June 21, 1994 concerning the Badger Army Ammunition Plant Site and your request for conceptual construction estimates for contaminated soil stabilization.

It is Geo-Con's opinion that the soil to be stabilized in the ditch areas can be done in-situ by utilizing Geo-Con's track mounted BOSS stabilizing system. The BOSS is a soil and sludge stabilization tool that mounts directly to the arm of a CAT 225 excavator. This system would work in conjunction with a mobile batch plant that would process a grout to be injected and mixed into the soil. It is anticipated that the grout reagent would be a 15% addition of Portland Type 1 cement, which would be mixed directly into the soil to a depth of two feet below grade.

The project approach would be for the track hoe with the BOSS to move along the trenches and stabilize the soil in one continuous manner. The challenge of this approach would be to be able to provide a mobile mix plant that would be able to produce enough grout to keep up with the production of the BOSS. Typically, the BOSS is able to stabilize up to 1000 cubic yards of soil per day.

The two lagoon areas would be able to be handled in the same manner, except that the excavator and the BOSS may have to work off of crane mats if the lagoon area is too soft to support equipment weight. A portable batch plant would be set up on shore and the grout would be pumped directly to the BOSS working off the crane mats.

The following pricing is conceptual in nature and is based upon many assumptions. As the details of the project become more defined, Geo-Con would be able to further develop the cost estimate as needed.

GEO·CON® INC.

Assumptions/Conditions

1. 36,000 lineal feet of trench is to be remediated. Approximately four feet wide, two feet deep, stabilizing the bottom two feet of soil.

2. Approximately 52,000 cubic yards of soil within the ditch is to be stabilized.

2a. Approximately 17,500 cubic yards of lagoon soil is to be stabilized.

3. Labor wages are based on prevailing labor rates.

4. All survey to be done by others.

5. All analytical to be done by others.

6. All perimeter air monitoring to be done by others.

7. Pricing includes dedicated health and safety personnel.

8. Assumes a 15% addition of Portland Type One cement as remedial reagent.

Ditch Stabilization Pricing

Mix Design Treatability Study	$ 30,000.00
Mobilization	$ 80,000.00
Stabilization	$ 35.00 PCY

Lagoon Stabilization Pricing

Mix Design Treatability Study	$ 30,000.00
Mobilization	$100,000.00
Stabilization	$ 45.00 PCY

If you have any questions regarding this letter, please do not hesitate to call me directly at (609) 772-1188

Sincerely,

GEO-CON, INC.

ROB LAROSE
District Manager

RL/efm

MCORR\R622ABB

ABB
ASEA BROWN BOVERI

ABB Environmental Services, Inc.
110 Free Street
P.O. Box 7050
Portland, Maine 04112-7050
Telephone (207) 775-5400
Fax (207) 772-4762

TELEPHONE MEMORANDUM

PROJECT NO.: 6853-09

DATE: 7/18/94

CLIENT: BADGER FS NG/RPA

PROJECT DESCRIPTION:

BETWEEN: PHIL MARTIN

AND: ROB LAROSE, GEOCON

SUBJECT: IN-SITU STABILIZATION/SOLIDIFICATION

Q & A FOLLOWING ROB LAROSE'S 6/24/94 LETTER TO ME

Q1) WHAT "FORM" DOES THE TREATED MATERIAL TAKE?
A - GRANULAR OR PELLETIZED FORM, NOT BLOCKS OR SLABS

Q2) IF BOTH DITCHES AND POND ARE REMEDIATED AT SAME TIME WHAT MOB FEE SHOULD BE USED? A - $100,000

Q3) WHAT WOULD THE COST BE OF A PILOT SCALE TEST?
A - $50,000

Q4) WHAT VOLUME INCREASE COULD BE EXPECTED? A - 10% TO 15%

Q5) IS SOME SORT OF STORAGE BUILDING REQUIRED FOR TREATMENT MATERIALS (i.e. CEMENT)? A - NO. CEMENT COMES IN TRAILERS.

Q6) IS A BETTER PHOTO/DRAWING OF "BOSS" EQUIPMENT AVAILABLE?
A - NO.

Q7) WHAT WOULD COSTS BE FOR AN EX-SITU S/S TREATMENT SYSTEM? A - WILL SUPPLY

DISTRIBUTION:
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110 Free Street
P.O. Box 7050
Portland, Maine 04112-7050
Telephone (207) 775-5400
Fax (207) 772-4762

TELEPHONE MEMORANDUM

PROJECT NO.: 6853-09 DATE: 7/20/94

CLIENT: BADGER FS NG/RPA

PROJECT DESCRIPTION:

BETWEEN: PHIL MARTIN

AND: ROB LAROSE, GEOCON

SUBJECT: EX-SITU STABILIZATION / SOLIDIFICATION COSTS

COSTS FOR A EX-SITU S/S TREATMENT SYSTEM ARE:
MOBILIZATION - $100,000
TREATMENT - $65/CY TO $70/CY
THRU-PUT - 1500 CY/DAY

Q) WHAT CONFIRMATORY SAMPLING WOULD HE EXPECT TO BE REQUIRED?
TCLP FOR METALS
FREEZE/THAW TEST FOR DURABILITY (COST ~ $500/EA)
FREQUENCY - VARIES MAYBE 1 PER 1000 CY

DISTRIBUTION:
ABB

1478-49

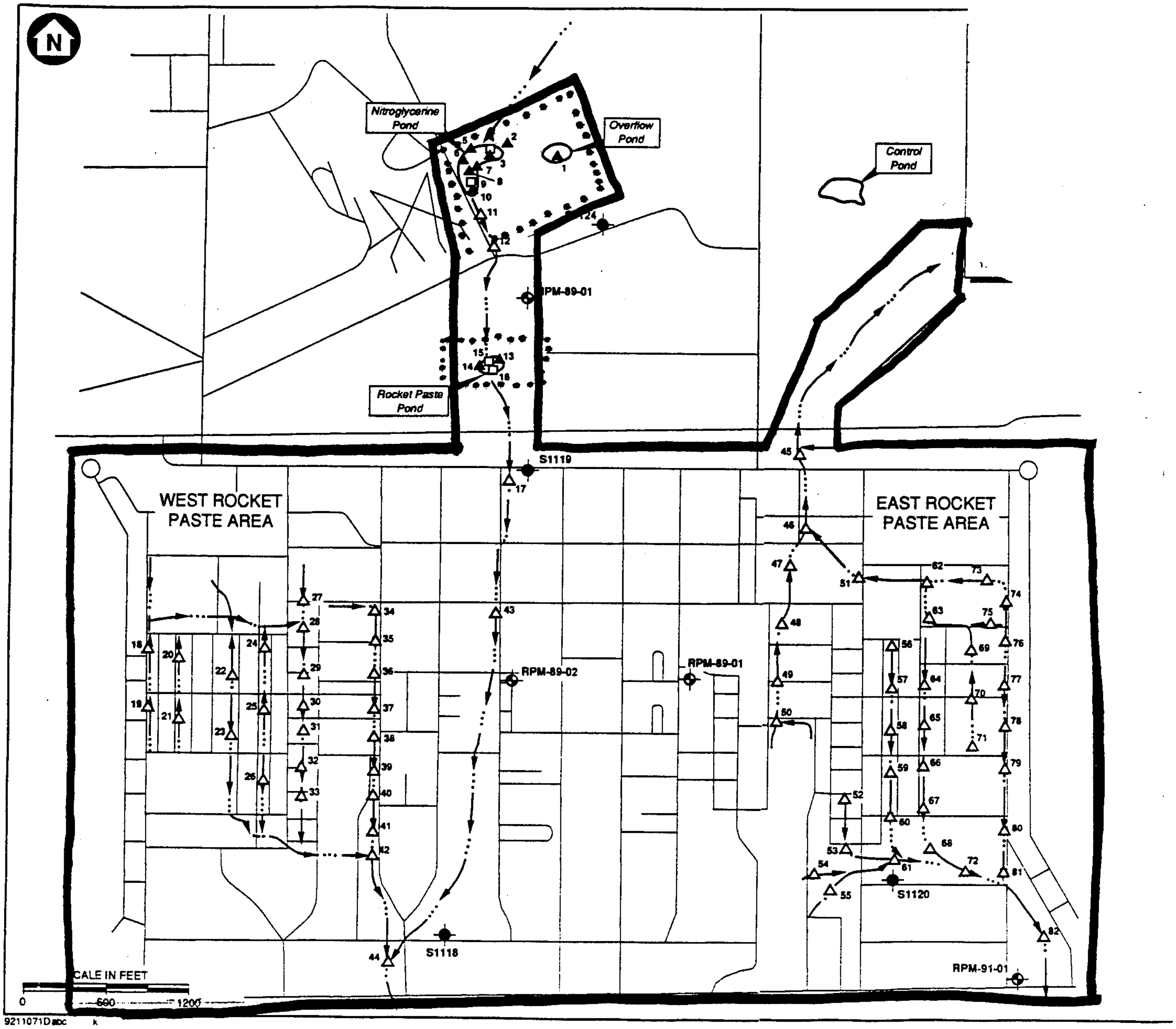
Form 4/6/90

APPENDIX F.3

MATERIAL USAGE

NITROGLYCERINE POND/ROCKET PASTE AREA

PROJECT BADGER FS NG/RPA FENCING	COMP. BY JeffR	JOB NO. 6853-09
	CHK. BY JSM	DATE 5/10/93



FENCING OPTION

SOIL/SEDIMENT (solid)

LENGTH = 6.5" + 3.5 + 2.5 + 2 + 1 + 0.8 + 0.5 + 1.3 + 1.5 + 0.8 + 1 + 0.8 + 1 + 0.3 + 1.7 + 3.5 = 28.7 in × $\frac{1200 \text{ ft}}{1.05 \text{ in}}$ = 32,800 feet

SURFACE WATER (dotted)

LENGTH = 0.7" + 0.3 + 0.7 + 0.3 + 0.7 + 1 + 0.7 + 1 = 5.4 × $\frac{1200 \text{ ft}}{1.05 \text{ in}}$ = 6,200 ft

PROJECT BADGER FS NG/RPA	COMP. BY Jeff R.	JOB NO. 6853-09
DITCH LENGTHS	CHK. BY JSM	DATE 5-10-93

MAIN DITCH

$1.8'' + 0.6 + 4 + 1.7 + 0.5 = 8.6 \times \frac{1200\text{ ft}}{1.65\text{ in}} = \underline{\underline{6,300\text{ ft}}}$

WEST ROCKET PASTE AREA

$1.9'' + 1.3 + 2 + 2 + 2.8 + 2.7 + 1 + 2.3 + 1.5 = 17.5 \times \frac{1200\text{ ft}}{1.65\text{ in}}$

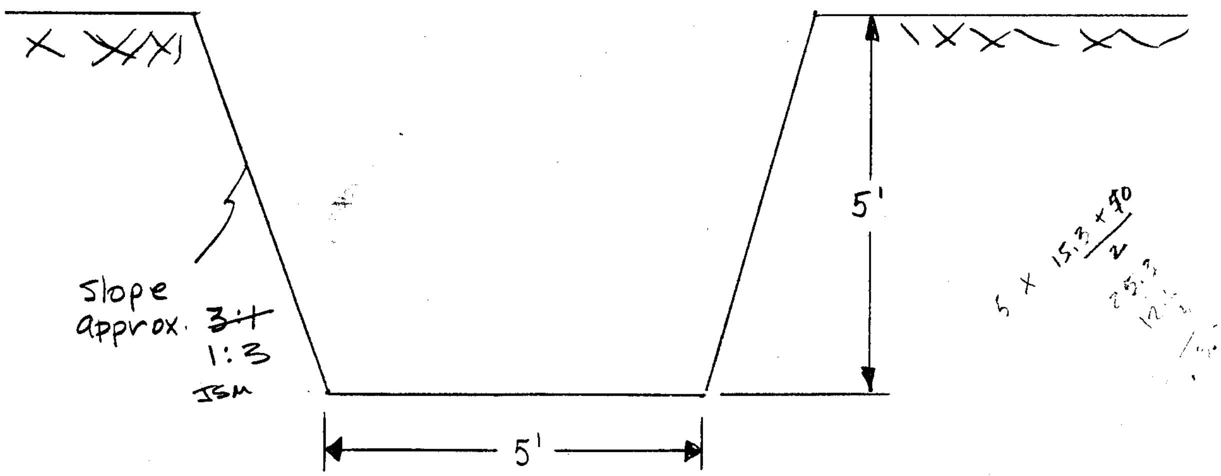
$= \underline{\underline{12,700\text{ ft}}}$

EAST ROCKET PASTE AREA

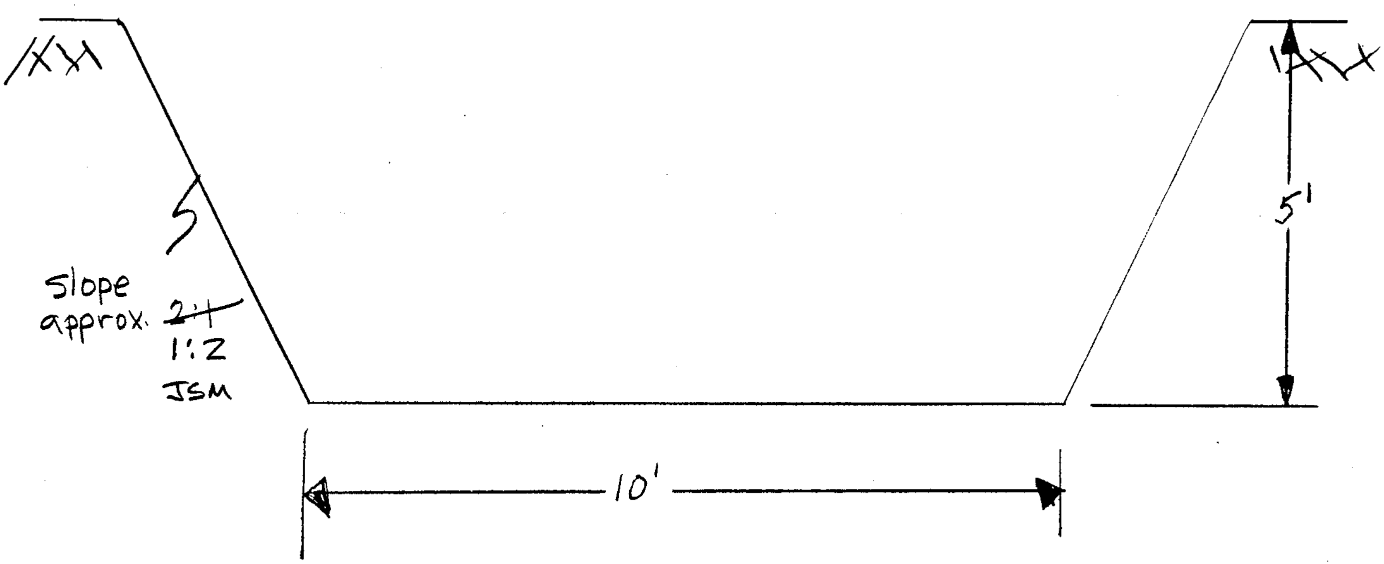
$2'' + 1 + 2.3 + 0.5 + 2.2 + 2.2 + 1.3 + 0.5 + 1 + 2.7 + 1.3 + 2 + 2 + 0.8 + 0.8$
$+ 1.5 + 0.5 = 24.6 \times \frac{1200\text{ ft}}{1.65\text{ in}} = \underline{\underline{17,900\text{ ft}}}$

MAIN DITCH	6,300 ft
W. RPA	12,700
E. RPA	17,900
TOTAL	36,900 ft

PROJECT BADGER FS NG/RPA	COMP. BY Jeff R	JOB NO. 6853-09
EXISTING DITCHES	CHK. BY JSM	DATE 5-19-93

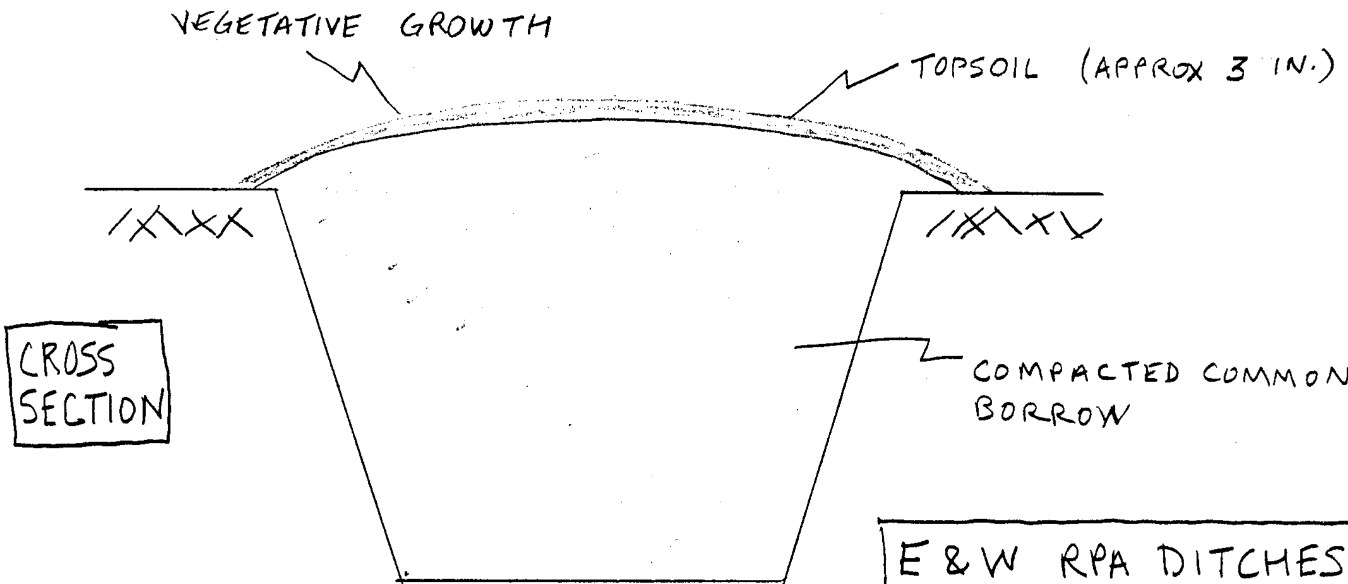


EXISTING E & W ROCKET PASTE AREA DITCH
CROSS SECTION (TYP.)



EXISTING MAIN ROCKET PASTE AREA DITCH
CROSS SECTION (TYP.)

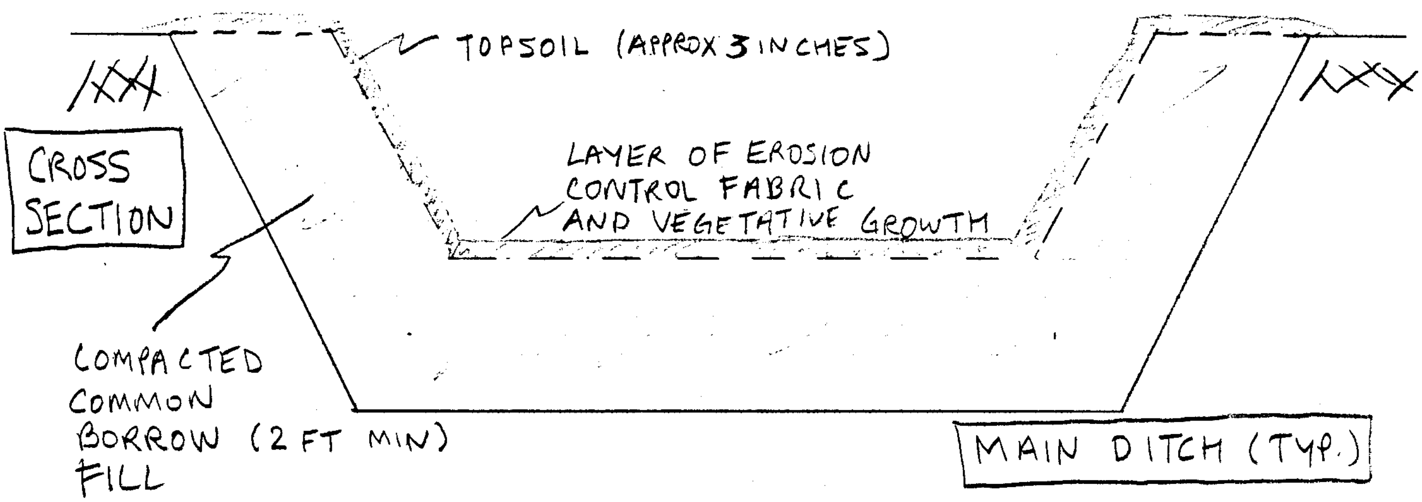
PROJECT BADGER FS NG/RPA DITCHES W/ SOIL COVER	COMP. BY Jeff R CHK. BY	JOB NO. 6853-09 DATE 7-21-93



E & W RPA DITCHES (TYP.)

AREA OF FILL = $5\,FT \times \frac{1}{2}(8.25\,FT + 5) + 4.6\,FT^2 = \underline{\underline{37.7\,FT^2}}$

AREA OF TOPSOIL = $\sim 10\,FT \times \frac{1}{4}\,FT = \underline{\underline{2.5\,FT^2}}$



MAIN DITCH (TYP.)

AREA OF FILL = $18\,FT \times 2\,FT = \underline{\underline{36\,FT^2}}$

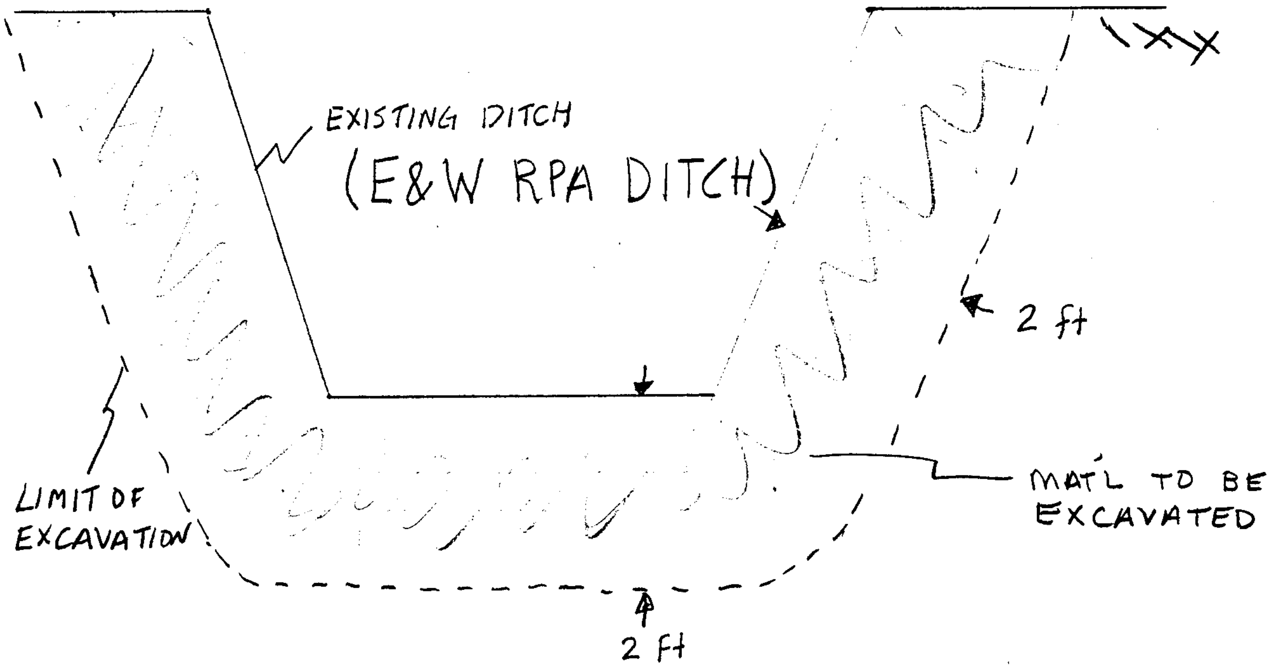
AREA OF TOPSOIL = $20\,FT \times \frac{1}{4}$ Foot = $\underline{\underline{5\,FT^2}}$

LENGTH OF EROSION CONTROL FABRIC $\underline{\underline{20\,FT}}$

PROJECT BADGER FS N G/RPA
DITCH EXCAVATION (TYP.)

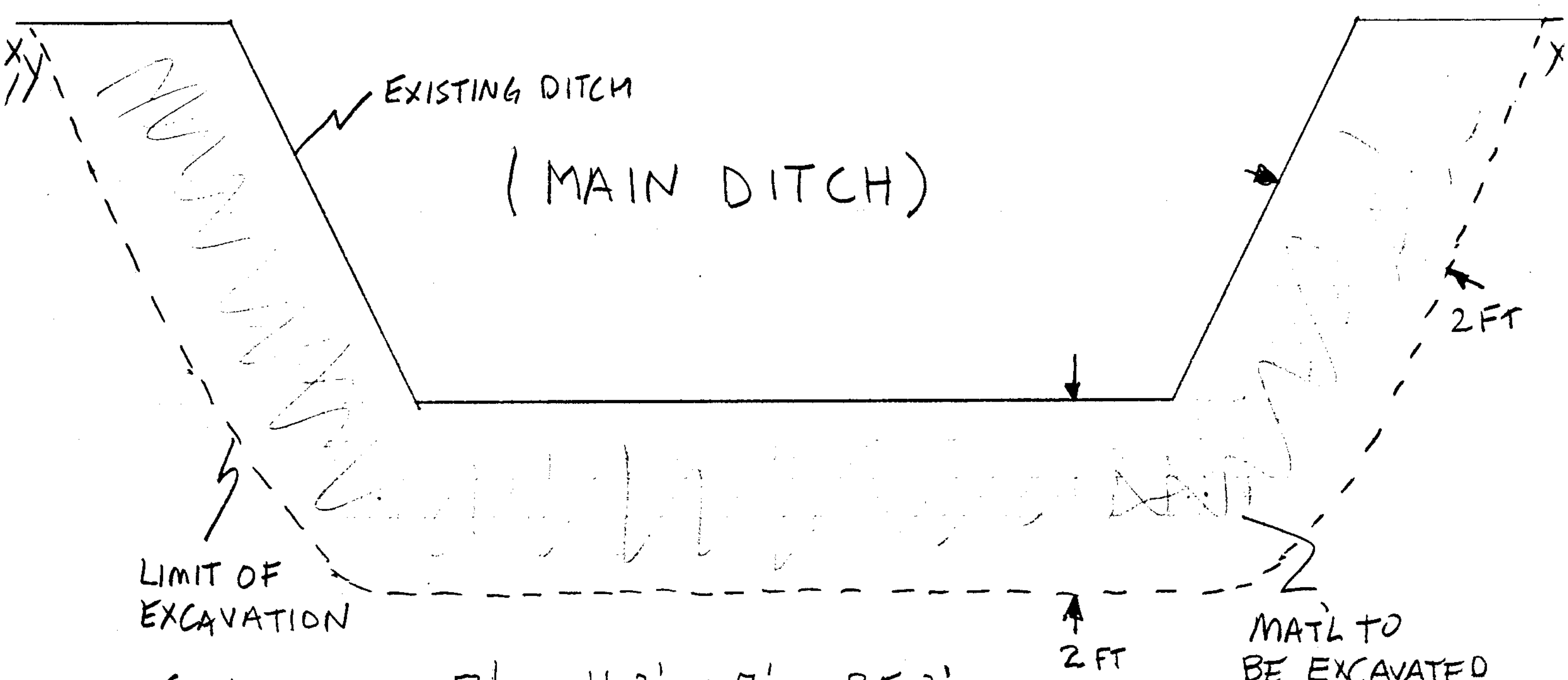
COMP. BY Je&R
CHK. BY JSM

JOB NO. 06853-09
DATE 5-20-93



℄ length = 6.25' + 6.5' + 6.25' = 19'

Excavation Area = 19' x 2' = <u>38</u> FT²



℄ LENGTH = 7' + 11.3' + 7' = 25.3'

EXCAVATION AREA = 25.3' x 2' = <u>51</u> FT²

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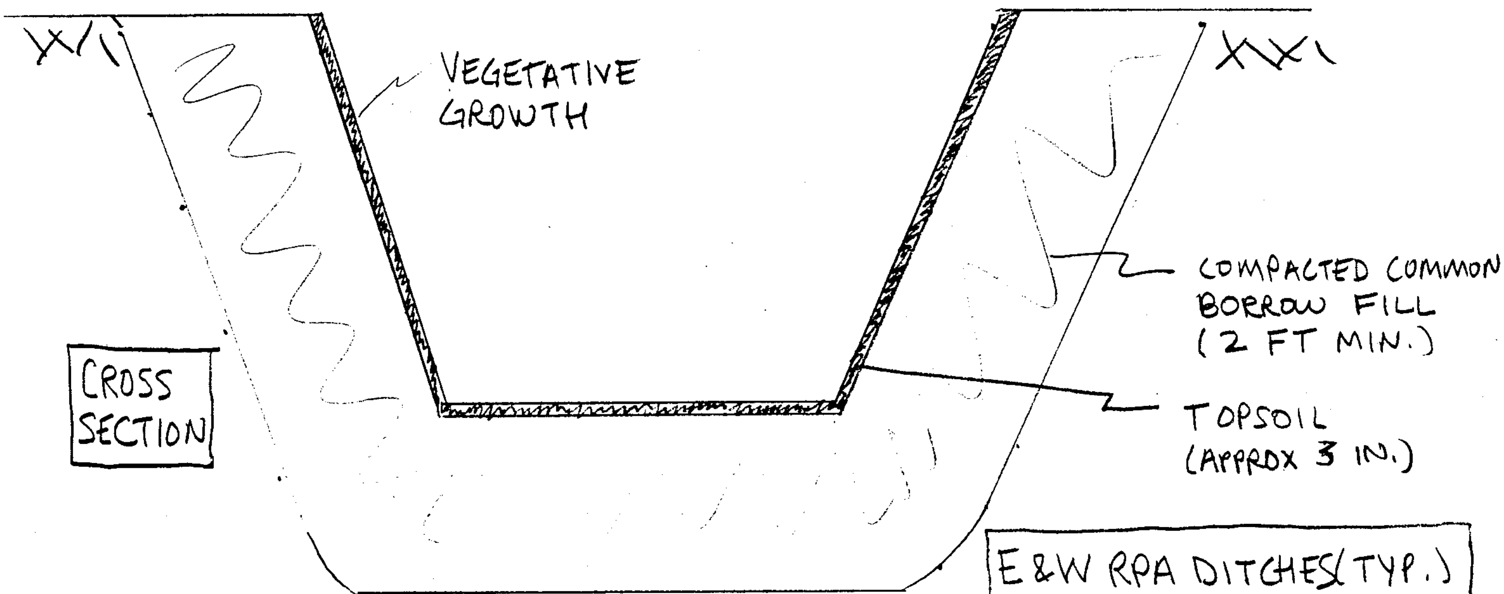
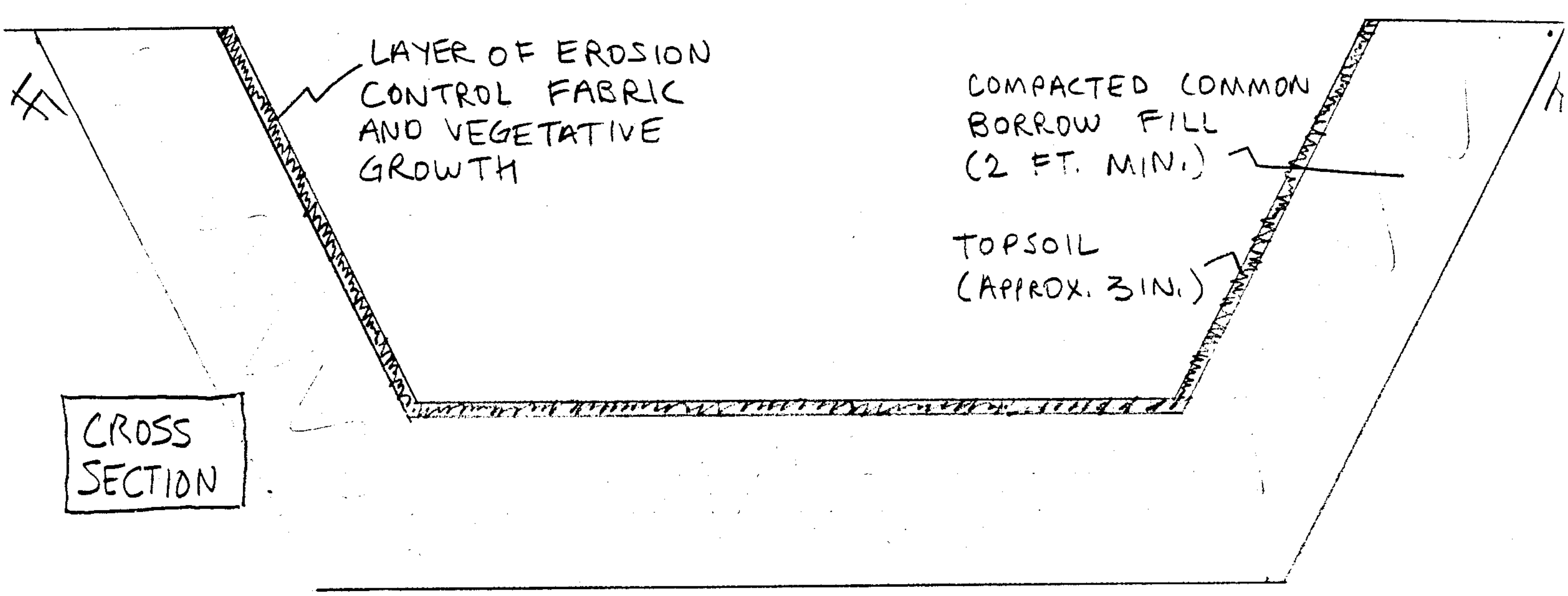
PROJECT BADGER FS NG/RPA DITCH BACKFILL	COMP. BY Jeff R	JOB NO. 06853-09
	CHK. BY JSM	DATE 5-20-93



AREA OF FILL $\cong$ 19' x 2' = $\underline{38\ FT^2}$

AREA OF TOPSOIL $\cong$ 16' x $\frac{3}{12}$ FT = $\underline{4\ FT^2}$



AREA OF FILL = 25.3' x 2' = $\underline{51\ FT^2}$ MAIN DITCH

AREA OF TOPSOIL = 21.5' x 3/12 FT = $\underline{5\ FT^2}$

LENGTH OF EROSION CONTROL FABRIC = $\underline{22\ FT}$

(7)

PROJECT BADGER FS NG/RPA SEDIMENT VOLUMES	COMP. BY Jeff R CHK. BY JSM	JOB NO. 6853-09 DATE 5-20-93

POND	APPROXIMATE AREA	
NITROGLYCERINE	160,000 FT^2	(RI)
ROCKET PASTE	45,000 FT^2	(RI)
OVERFLOW	30,000 FT^2	(ESTIMATED)

EXCAVATION

NITROGLYCERINE POND $160{,}000\ FT^2 \times 2\ FT\ DEPTH \times \frac{YD^3}{27 FT^3} = 12{,}000\ YD^3$

ROCKET PASTE POND $45{,}000\ FT^2 \times 2\ FT\ DEPTH \times \frac{1}{27} = 3{,}300\ YD^3$

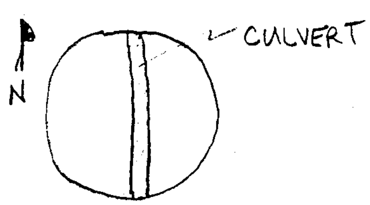
OVERFLOW POND $30{,}000\ FT^2 \times 2\ FT\ DEPTH \times \frac{1}{27} = 2{,}200\ YD^3$

TOTAL = $\underline{17{,}500\ YD^3}$

SOIL COVER OR EXCAVATION BACKFILL

NITROGLYCERINE POND	BACKFILL TOPSOIL	$12{,}000\ YD^3$ $160{,}000\ FT^2 \times \frac{3\ IN}{12} \times \frac{1}{27} = 1{,}500\ YD^3$
ROCKET PASTE POND	BACKFILL TOPSOIL	$3{,}300\ YD^3$ $45{,}000\ FT^2 \times \frac{3}{12} \times \frac{1}{27} = 420\ YD^3$
OVERFLOW POND	BACKFILL TOPSOIL	$2{,}200\ YD^3$ $30{,}000\ FT^2 \times \frac{3}{12} \times \frac{1}{27} = 280\ YD^3$
TOTAL	BACKFILL TOPSOIL	$\underline{17{,}500\ YD^3}$ $\underline{2{,}200\ YD^3}$

CULVERT FOR ROCKET PASTE POND



ROCKET PASTE POND
(PLAN VIEW)

CULVERT LENGTH $= \sqrt{\frac{AREA * 4}{\pi}} = \sqrt{\frac{45{,}000\ FT^2 * 4}{\pi}}$

$= \underline{240\ FT}$

SIZE 2 FT DIAMETER

FORM 00.01 REV. 4/81 ABB Environmental Services, Inc.

PROJECT BADGER FS NG/RPA	COMP. BY Jeff R	JOB NO. 6853-09
SURFACE WATER VOLUMES	CHK. BY JBM	DATE 5-10-93

7.481 gal = 1 ft^3

NITROGLYCERINE POND

AREA APPROX. 160,000 FT^2 (RI)
MAX DEPTH APPROX. 3 TO 5 FEET (RI)

ROCKET PASTE POND

AREA APPROX. 45,000 FT^2 (RI)
MAX DEPTH APPROX 1/2 TO 1 FOOT DEEP (RI)

OVERFLOW POND

AREA 30,000 (ESTIMATED)
DEPTH 1 FOOT

POND	(FT^2) AREA	(FT) DEPTH	VOLUME (FT^3)	VOLUME (GAL)
NITROGLYCERINE	160,000	4	640,000	4,800,000
ROCKET PASTE	45,000	1	45,000	340,000
OVERFLOW	30,000	1	30,000	220,000
TOTAL			715,000	5,300,000

PROJECT BADGER FS NG/RPA	COMP. BY Jeff	JOB NO. 06853-09
VOLUMES FOR NG/RPA-SS2	CHK. BY	DATE 7-21-93

SOIL COVER

COMMON BORROW

	CROSS SECTIONAL AREA	DITCH LENGTH	VOLUME
W. ROCKET PASTE DITCHES	37.7 FT^2	12,700 FT	17,700 YD^3
E. ROCKET PASTE DITCHES	37.7 FT^2	17,900 FT	25,000 YD^3
MAIN DITCH	36 FT^2	6,300 FT	8,400 YD^3
NITROGLYCERINE POND			12,000 YD^3
ROCKET PASTE POND			3,300 YD^3
OVERFLOW POND			2,200 YD^3
	TOTAL		69,000 YD^3

TOP SOIL

W ROCKET PASTE DITCHES	2.5 FT^2	12,700 FT	1,200 YD^3
E ROCKET PASTE DITCHES	2.5 FT^2	17,900 FT	1,700 YD^3
MAIN DITCH	5 FT^2	6,300 FT	1,200 YD^3
NITROGLYCERINE POND			1,500 YD^3
ROCKET PASTE POND			420 YD^3
OVERFLOW POND			280 YD^3
	TOTAL		6,300 YD^3

EROSION CONTROL FABRIC

FOR MAIN DITCH 20 FT x 6,300 FT = 14,000 YD^2

CULVERT

FOR ROCKET PASTE POND 240 FT LONG

(2 FT DIA.)

(10)

PROJECT BADGER FS NG/RPA VOLUMES FOR NG/RPA-553 AND NG/RPA-554	COMP. BY Jeff R	JOB NO. 6853-09
	CHK. BY JSM	DATE 5-20-93

COMMON BORROW	CROSS-SECTIONAL AREA	DITCH LENGTH	VOLUME
W. ROCKET PASTE DITCHES	38 FT²	12,700 FT	17,900 YD³
E. ROCKET PASTE DITCHES	38 FT²	17,900 FT	25,200 YD³
MAIN DITCH	51 FT²	6,300 FT	11,900 YD³
NITROGLYCERINE POND			12,000 YD³
ROCKET PASTE POND			3,300 YD³
OVERFLOW POND			2,200 YD³

TOTAL 72,500 YD³

TOP SOIL			
W. ROCKET PASTE DITCHES	4 FT²	12,700 FT	1,900 YD³
E. ROCKET PASTE DITCHES	4 FT²	17,900 FT	2,700 YD³
MAIN DITCH	5 FT²	6,300 FT	1,200 YD³
NITROGLYCERINE POND			1,500 YD³
ROCKET PASTE POND			420 YD³
OVERFLOW POND			280 YD³

TOTAL 8000 YD³

EXCAVATION			
W. ROCKET PASTE DITCHES	38 FT²	12,700 FT	17,900 YD³
E. ROCKET PASTE DITCHES	38 FT²	17,900 FT	25,200 YD³
MAIN DITCH	51 FT²	6,300 FT	11,900 YD³
NITROGLYCERINE POND			12,00 YD³
ROCKET PASTE POND			3,300 YD³
OVERFLOW POND			2,200 YD³

SUBTOTAL SOIL 55,000 YD³
SEDIMENT 17,500 YD³
TOTAL 72,500 YD³

PROJECT BADGER F S NG/RPA	COMP. BY PRM	JOB NO. 6853-09
VOLUMES FOR NG/RPA - SS3 & -SS4	CHK. BY	DATE 7-18-94

COMMON BORROW

HAVE TO ADD FILLING OVERFLOW & ROCKET PASTE PONDS WITH 1' COMMON BORROW.

THIS IS EQUAL TO 1/2 OF THEIR VOLUME OR AN ADDITONAL 2750 cy.

"TOPSOIL" REMAINS UNCHANGED.

PROJECT	COMP. BY	JOB NO.
BADGER FS	PRM	6853-09
NSG/PPA	CHK. BY	DATE
		6-28-94

AREA ENCLOSED BY MINIMAL ACTION FENCING (SS/SSD)

$6.35 \times 3.35 =$	21.27 SI
$2.05 \times 0.50 =$	1.03
$\frac{1}{2} \times 0.17 \times 0.70 =$	0.06
$\frac{1}{2} \times 0.92 \times (0.10+0.40) =$	0.23
$0.25 \times 0.65 =$	0.16
$\frac{1}{2} \times 0.20 \times 0.50 =$	0.05
$\frac{1}{2} \times 0.75 \times 0.08 =$	0.03
$\frac{1}{2} \times 0.85 \times (0.12+0.25) =$	0.16

$$22.99\ SI \times \left(1200\ \frac{LF}{1IN}\right)^2 \times \frac{1\ AC}{43560\ SF}$$

$= 760\ AC.$

AREA ENCLOSED BY MINIMAL ACTION FENCING (SW)

$0.61 \times 0.27 = 0.16$ SI

$0.65 \times 0.80 = 0.52$

$$0.68\ SI \times \left(1200\ \frac{LF}{1IN}\right)^2 \times \frac{1\ AC}{43560\ SF}$$

$= 22\ AC$

PROJECT	COMP. BY	JOB NO.
CONFIRMATION DELINEATION SAMPLING	PRM	6853-09
	CHK. BY	DATE
		7-14-94

WEST ROCKET PASTE AREA

$12700 \text{ LF DITCH} / 25 \text{ SAMPLES} = 508 \frac{\text{LF DITCH}}{\text{SAMPLE}}$

EAST ROCKET PASTE AREA

$17900 \text{ LF DITCH} / 38 \text{ SAMPLES} = 471 \frac{\text{LF DITCH}}{\text{SAMPLE}}$

USE $500 \frac{\text{LF DITCH}}{\text{SAMPLE}}$

MAIN DITCH - NG POND TO RP POND

$1200 \text{ LF} \times \frac{1 \text{ SAMPLE}}{500 \text{ LF}} \approx 3 \text{ SAMPLES}$

ALREADY HAVE 2 ADD 1

MAIN DITCH - RP POND TO SOUTH BOUNDARY RP AREA

$5000 \text{ LF} \times \frac{1 \text{ SAMPLE}}{500 \text{ LF}} = 10 \text{ SAMPLE}$

ALREADY HAVE 3 ADD 7

IN MAIN DITCH ADD 8 SURFACE SAMPLES ALONG ITS LENGTH. THIS WILL CONFIRM SURFACE SOIL CONTAMINATION

AT OR NEAR EACH SOIL/SEDIMENT SAMPLE (78 EXISTING + 8 NEW = 86 TOTAL) TAKE SAMPLE FROM 2' & 4' BGS. FOR 25% OF SAMPLES (86 × 0.25 = 22 LOCATIONS) ACROSS SITE TAKE SAMPLE AT 6' BGS.

WILL NEED 8 SURFACE SAMPLES

86 BORINGS

194 SAMPLES FROM BORINGS.

PROJECT BADGER SS-5 NG/RPA IN-SITU S/S SOIL COVER	COMP. BY PRM	JOB NO. 6853-09
	CHK. BY	DATE 7/15/94

E & W ROCKET PASTE AREA DITCHES

COMMON SOIL COVER

$\frac{1}{2} \times (5 + 8.3) \times 5 = 33$ CF/LF

$13.5 \times 2 = 27$

$2 \times \frac{1}{2} \times 2 \times 4 = 8$

DEDUCT $\frac{1}{2} \times 5.2 \times 1.7 = \langle 4 \rangle$

62 CF/LF $\times \frac{1}{27} = 2.30$ CY/LF

VEGETATIVE SOIL

$2 \times 4.5 \times 0.5 = 4.5$ CF/LF

$2 \times 4 \times 0.5 = 4$

$2 \times 3 \times 0.5 = 3$

11.5 CF/LF $\times \frac{1}{27} = 0.43$ CY/LF

MAIN DITCH

COMMON SOIL

$2 \times \frac{1}{2} \times 2 \times 4 = 8$ CF/LF

$2 \times 3.5 \times 2 = 14$

$2 \times 5.5 \times 2 = 22$

$8.5 \times 2 = 17$

61 CF/LF $\times \frac{1}{27} = 2.26$ CY/LF

VEGETATIVE SOIL

$2 \times 4.5 \times 0.5 = 4.5$ CF/LF

$2 \times 4 \times 0.5 = 4$

$2 \times 5.5 \times 0.5 = 5.5$

$7 \times 0.5 = 3.5$

17.5 CF/LF $\times \frac{1}{27} = 0.65$ CY/LF

PROJECT BADGER SS-5 NG/RPA IN-SITU S/S SOIL COVER	COMP. BY PRM	JOB NO. 6853-09
	CHK. BY	DATE 7/15/94

COMMON SOIL COVER

W. ROCKET PASTE DITCHES	12700 LF × 2.30 CY/LF =	29200 CY
E. ROCKET PASTE DITCHES	17900 LF × 2.3 CY/LF =	41200
MAIN DITCH	6300 LF × 2.26 CY/LF =	14200
NITROGLYCERINE POND	(FROM SS2 SOIL COVER)	12,000
OVERFLOW POND	(FROM SS2 SOIL COVER)	2,200
ROCKET PASTE POND	(FROM SS2 SOIL COVER)	3,300
	TOTAL	130,100 CY

VEGETATIVE SOIL

W. ROCKET PASTE DITCHES	12700 LF × 0.43 CY/LF =	5500 CY
E. ROCKET PASTE DITCHES	17900 LF × 0.43 CY/LF =	7700
MAIN DITCH	6300 LF × 0.65 CY/LF =	4100
NITROGLYCERINE POND	(TWICE SS2 SOIL COVER)	3000
OVERFLOW POND	(TWICE SS2 SOIL COVER)	560
ROCKET PASTE POND	(TWICE SS2 SOIL COVER)	840
	TOTAL	21700 CY

PROJECT BADGER SS-5 NG/RPA IN-SITU S/S SOIL COVER	COMP. BY PRM	JOB NO. 6853-09
	CHK. BY	DATE 7/15/94

AREA OF SEEDING

W. ROCKET PASTE DITCHES	12700LF × 22 SF/LF =	279400 SF
E. ROCKET PASTE DITCHES	17900LF × 22 SF/LF =	393800
MAIN DITCH	6300LF × 37 SF/LF =	233100
NITROGLYCERINE POND		160,000
OVERFLOW POND		30,000
ROCKET PASTE POND		45,000
		1141300 SF
		÷43560 SF/AC
TOTAL		26.2 AC

FORM 00.01 REV. 4/81

ABB Environmental Services, Inc.

APPENDIX G

SETTLING PONDS AND SPOILS DISPOSAL AREA

APPENDIX G.1

COSTS

SETTLING PONDS AND SPOILS DISPOSAL AREA

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SS-1 MINIMAL ACTION
LOCATION: SETTLING PONDS
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SS-1 MINIMAL ACTION COST SUMMARY TABLE DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
DIRECT COST OF OPTION SS-1 MINIMAL ACTION				
INSTITUTIONAL CONTROLS				$10,000
TOTAL DIRECT COST OF OPTION SS-1 MINIMAL ACTION				$10,000
INDIRECT COST OF OPTION SS-1 MINIMAL ACTION				
HEALTH AND SAFETY			5.00%	$0
LEGAL, ADMIN, PERMITTING			5.00%	0
ENGINEERING			10.00%	0
SERVICES DURING CONSTRUCTION			10.00%	0
TOTAL INDIRECT COST OF OPTION SS-1 MINIMAL ACTION				$0
TOTAL CAPITAL (DIRECT + INDIRECT) COST				$10,000
OPERATING AND MAINTENANCE COSTS				
TOTAL COST REPLACEMENT WELLS				$11,000
TOTAL PRESENT WORTH OF REPLACEMENT WELLS IN YEAR 16 @ 5%				$5,000
TOTAL ANNUAL OPERATING AND MAINTENANCE COSTS				$185,000
TOTAL PRESENT WORTH OF ANNUAL O&M COSTS (5% FOR THIRTY YEARS)				$2,844,000
TOTAL PRESENT WORTH OF OPERATING AND MAINTENANCE COSTS				$2,849,000
TOTAL COST OF OPTION SS-1 MINIMAL ACTION				$2,859,000

DATE:04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SS-1 MINIMAL ACTION
LOCATION: SETTLING PONDS
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SS-1 MINIMAL ACTION

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
INSTITUTIONAL CONTROLS	1	LS	10000.00	$10,000
OPERATING & MAINTENANCE COSTS				
REPLACEMENT WELLS	1	EA	10000.00	$10,000
CONTINGENCY ~10%				1,000
TOTAL COST REPLACEMENT WELLS				$11,000
ANNUAL OPERATING & MAINTENANCE COSTS				
GROUNDWATER SAMPLING & ANNALYSIS	1	LS	161000.00	$161,000
EDUCATIONAL PROGRAMS	1	LS	5000.00	5,000
FIVE YEAR SITE REVIEW @ $10,000 EVERY FIVE YEARS	1	LS	1809.75	1,810
CONTINGENCY ~10%				17,190
TOTAL ANNUAL OPERATING & MAINTENANCE COSTS				$185,000

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION SS-3 CAPPING
JOB # 6853-09
LOCATION: SETTLING PONDS
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SS-3 CAPPING COST SUMMARY TABLE DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
DIRECT COST OF OPTION SS-3 CAPPING				
SITE PREPARATION AND MOB/DEMOB				$903,000
CONTAMINATED SOIL DELINEATION				111,000
CAP				22,543,000
SURFACE WATER MANAGEMENT				123,000
TOTAL DIRECT COST OF OPTION SS-3 CAPPING				$23,680,000
INDIRECT COST OF OPTION SS-3 CAPPING				
HEALTH AND SAFETY			5.00%	$1,184,000
LEGAL, ADMIN, PERMITTING			5.00%	1,184,000
ENGINEERING			10.00%	2,368,000
SERVICES DURING CONSTRUCTION			10.00%	2,368,000
TOTAL INDIRECT COST OF OPTION SS-3 CAPPING				$7,104,000
TOTAL CAPITAL (DIRECT + INDIRECT) COST				$30,784,000
OPERATING AND MAINTENANCE COSTS				
TOTAL ANNUAL POST CLOSURE MAINTENANCE COSTS				$196,000
TOTAL PRESENT WORTH OF O&M COSTS (5% FOR THIRTY YEARS)				$3,013,000
TOTAL COST OF OPTION SS-3 CAPPING				$33,797,000

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION SS-3 CAPPING
LOCATION: SETTLING PONDS
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

JOB # 6853-09

ESTIMATOR: P. R. MARTIN

OPTION SS-3 CAPPING SITE PREPARATION AND MOB/DEMOB DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
EQUIPMENT (IN OR OUT)				
FRONT END LOADER	4	EA	520.00	$2,080
DUMP TRUCKS	8	EA	260.00	2,080
BACKHOE	4	EA	520.00	2,080
DOZER	8	EA	1000.00	8,000
SHEEPSFOOT ROLLER	8	EA	575.00	4,600
VIBRATING COMPACTOR	8	EA	600.00	4,800
OFFICE TRAILER	18	MON	155.00	2,790
STORAGE TRAILER (2 EA)	36	MON	155.00	5,580
TRAILER SET-UP & DELIVERY, REMOVAL	3	EA	310.00	930
TOILET (2 EA*1.5 YR/EA*52 WK/YR)	156	WK	25.00	3,900
WATER CLR (2EA*1.5YR/EA*52WK/YR)	156	WK	25.00	3,900
WATER (156 WK * 5 DAY/WK)	780	DAY	15.00	11,700
TELEPHONE SERVICE	18	MON	520.00	9,360
ELECTRICAL HOOK-UP	1	LS	2500.00	2,500
ELECTRICAL POWER	18	MON	300.00	5,400
PICK-UP (2 EA * 18 MON/EA)	36	MON	1035.00	37,260
OFFICE EQUIPMENT	18	MON	1035.00	18,630
PUMPS, TOOLS MINOR EQUIPMENT	1	LS	5000.00	5,000
CLEAR SOIL STOCKPILE AREA				
CLEAR & GRUB LIGHT VEGETATION	3	AC	3825.00	11,475
GRADE	4950	CY	2.00	9,900
GRAVEL - 12" THICK	14520	SY	3.50	50,820
PARKING AREA				
CLEAR & GRUB LIGHT VEGETATION	0.5	AC	3825.00	1,913
GRADE	825	CY	2.00	1,650
GRAVEL - 12" THICK	2420	SY	3.50	8,470
TOTAL THIS PAGE				$214,818

DATE:04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION SS-3 CAPPING
LOCATION: SETTLING PONDS
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

JOB # 6853-09

ESTIMATOR: P. R. MARTIN

OPTION SS-3 CAPPING SITE PREPARATION AND MOB/DEMOB DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
TOTAL PAGE 2				$214,818
DECON PAD	1	LS	10000.00	10,000
LABORER (2 MEN*10 DAY/MAN*8 HR/DAY)	160	MNHR	30.50	4,880
CARPENTER (2 MEN*10 DAY/MAN*8 HR/DAY)	160	MNHR	39.00	6,240
ELECTRICIAN (2 MEN*10 DAY/MAN*8 HR/DAY	160	MNHR	42.50	6,800
SITE SUPERINTENDANT (18 MON*210 HR/MON	3780	MNHR	62.25	235,305
FOREMAN (18 MON * 210 HR/MON)	3780	MNHR	51.75	195,615
CLERK/TYPIST (18 MON * 168 HR/MON)	3024	MNHR	26.00	78,624
UNDEVELOPED DESIGN DETAILS ~20%				150,719
TOTAL SITE PREPARATION AND MOB/DEMOB				$903,000

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION SS-3 CAPPING JOB # 6853-09
LOCATION: SETTLING PONDS
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SS-3 CAPPING CONTAMINATED SOIL DELINEATION DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
SAMPLE COLLECTION	200	HR	56.00	$11,200
ON-SITE ANALYSIS	30	DAY	2600.00	78,000
OFF-SITE CONFIRMATORY ANALYSIS	50	SMPL	60.00	3,000
UNDEVELOPED DESIGN DETAILS ~20%				18,800
TOTAL CONTAMINATED SOIL DELINEATION				$111,000

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SS-3 CAPPING
LOCATION: SETTLING PONDS
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SS-3 CAPPING CAP DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
CAP				
BORROW STUDIES	1	LS	60000.00	$60,000
COMMON BORROW	1220000	CY	4.00	4,880,000
SPREAD & COMPACT COMMON BORROW	1220000	CY	2.00	2,440,000
CLAY	268000	CY	8.00	2,144,000
SPREAD & COMPACT CLAY	268000	CY	4.00	1,072,000
DRAINAGE SAND	134000	CY	8.00	1,072,000
SPREAD & COMPACT DRAINAGE SAND	134000	CY	4.00	536,000
GEOMEMBRANE - 60 MIL VLDPE	400000	SY	8.00	3,200,000
GEOTEXTILE	400000	SY	4.00	1,600,000
TOP SOIL	134000	CY	10.00	1,340,000
SPREAD & COMPACT	134000	CY	2.00	268,000
SEED, FERTILIZE, MULCH	87	AC	2000.00	174,000
UNDEVELOPED DESIGN DETAILS ~20%				3,757,000
TOTAL CAP				$22,543,000

DATE:04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION SS-3 CAPPING
JOB # 6853-09
LOCATION: SETTLING PONDS
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SS-3 CAPPING SURFACE WATER MANAGEMENT DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
SURFACE WATER MANAGEMENT				
DITCH EXCAVATION, BERM CONSTR	17100	CY	3.00	$51,300
DITCH BACKFILL & COMPACT	17100	CY	3.00	51,300
UNDEVELOPED DESIGN DETAILS ~20%				20,400
TOTAL SURFACE WATER MANAGEMENT				$123,000

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SS-3 CAPPING
LOCATION: SETTLING PONDS
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SS-3 CAPPING POST CLOSURE MAINTENANCE DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
ANNUAL COSTS				
ANNUAL INSPECTION & REPORT	8	HR	50.00	$400
GROUNDWATER SAMPLING & ANALYSIS	1	LS	161000.00	161,000
MAINTENANCE ITEMS OCCURING EVERY 5 YEARS				
SITE REVIEW	1	LS	10000.00	$10,000
		SUBTOTAL		$10,000
ANNUALIZED COST OF MAINTENANCE ITEMS OCCURING EVERY 5 YEARS				1,810
SUBTOTAL ANNUAL COSTS				$163,210
UNDEVELOPED DESIGN DETAILS ~20%				32,790
TOTAL ANNUAL POST CLOSURE MAINTENANCE COSTS				$196,000

DATE:04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SS-7 MODIFIED IN-SITU SOLIDIFICATION AND SOIL COVER

LOCATION: SETTLING PONDS
BADGER ARMY AMMUNITION PLANT

ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SS-7 MODIFIED IN-SITU SOLIDIFICATION AND SOIL COVER
COST SUMMARY TABLE

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
DIRECT COST OF OPTION SS-7 MODIFIED IN-SITU SOLIDIFICATION AND SOIL COVER				
TREATABILITY TESTING				$78,000
SITE PREPARATION AND MOB/DEMOB				3,099,000
CONTAMINATED SOIL DELINEATION				221,000
IN-SITU STABILIZATION/SOLIDIFICATION				14,081,000
STABILIZATION/SOLIDIFICATION				24,351,000
COVER SOIL				7,646,000
SURFACE WATER MANAGEMEMT				123,000
TOTAL DIRECT COST OF OPTION SS-7 MODIFIED IN-SITU SOLIDIFICATION AND SOIL COVER				$49,599,000
INDIRECT COST OF OPTION SS-7 MODIFIED IN-SITU SOLIDIFICATION AND SOIL COVER				
HEALTH AND SAFETY			5.00%	$2,480,000
LEGAL, ADMIN, PERMITTING			5.00%	2,480,000
ENGINEERING			10.00%	4,960,000
SERVICES DURING CONSTRUCTION			10.00%	4,960,000
TOTAL DIRECT COST OF OPTION SS-7 MODIFIED IN-SITU SOLIDIFICATION AND SOIL COVER				$14,880,000
TOTAL CAPITAL (DIRECT + INDIRECT) COST				$64,479,000
OPERATING AND MAINTENANCE COSTS				
TOTAL ANNUAL POST CLOSURE MAINTENANCE COSTS				$196,000
TOTAL PRESENT WORTH OF O&M COSTS (5% FOR THIRTY YEARS)				$3,013,000
TOTAL COST OF OPTION SS-7 MODIFIED IN-SITU SOLIDIFICATION AND SOIL COVER				$67,492,000

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SS-7 MODIFIED IN-SITU SOLIDIFICATION AND SOIL COVER

LOCATION: SETTLING PONDS
BADGER ARMY AMMUNITION PLANT

ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SS-7 MODIFIED IN-SITU SOLIDIFICATION AND SOIL COVER
SITE PREPARATION AND MOB/DEMOB

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
EQUIPMENT (IN OR OUT)				
FRONT END LOADER	8	EA	520.00	$4,160
DUMP TRUCKS	80	EA	260.00	20,800
BACKHOE	8	EA	520.00	4,160
DOZER	8	EA	1000.00	8,000
OFFICE TRAILER	24	MON	155.00	3,720
STORAGE TRAILER (2 EA)	48	MON	155.00	7,440
TRAILER SET-UP & DELIVERY, REMOVAL	3	EA	310.00	930
TOILET (2 EA*2 YR/EA*52 WK/YR)	208	WK	25.00	5,200
WATER CLR (2EA*2 YR/EA*52WK/YR)	208	WK	25.00	5,200
WATER (208 WK * 5 DAY/WK)	1040	DAY	15.00	15,600
TELEPHONE SERVICE	24	MON	520.00	12,480
ELECTRICAL HOOK-UP	1	LS	2500.00	2,500
ELECTRICAL POWER	24	MON	300.00	7,200
PICK-UP (2 EA * 24 MON/EA)	48	MON	1035.00	49,680
OFFICE EQUIPMENT	24	MON	1035.00	24,840
PUMPS, TOOLS MINOR EQUIPMENT	1	LS	5000.00	5,000
STOCKPILE AREA				
CLEAR & GRUB LIGHT VEGETATION	15	AC	3825.00	57,375
GRADE	74250	CY	2.00	148,500
GRAVEL - 12" THICK	217800	SY	3.50	762,300
GEOMEMBRANE	15	AC	35000.00	525,000
PARKING AREA				
CLEAR & GRUB LIGHT VEGETATION	0.5	AC	3825.00	1,913
GRADE	825	CY	2.00	1,650
GRAVEL - 12" THICK	2420	SY	3.50	8,470
TOTAL THIS PAGE				$1,682,118

DATE:04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SS-7 MODIFIED IN-SITU SOLIDIFICATION AND SOIL COVER

LOCATION: SETTLING PONDS
BADGER ARMY AMMUNITION PLANT

ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SS-7 MODIFIED IN-SITU SOLIDIFICATION AND SOIL COVER
SITE PREPARATION AND MOB/DEMOB

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
TOTAL PAGE 2				$1,682,118
DECON PAD	1	LS	10000.00	10,000
STORAGE BUILDING	5000	SF	35.00	175,000
LABORER (2 MEN*20 DAY/MAN*8 HR/DAY)	320	MNHR	30.50	9,760
CARPENTER (2 MEN*20 DAY/MAN*8 HR/DAY)	320	MNHR	39.00	12,480
ELECTRICIAN (2 MEN*20 DAY/MAN*8 HR/DAY	320	MNHR	42.50	13,600
SITE SUPERINTENDANT (24 MON*210 HR/MON	5040	MNHR	62.25	313,740
FOREMAN (24 MON * 210 HR/MON)	5040	MNHR	51.75	260,820
CLERK/TYPIST (24 MON * 168 HR/MON)	4032	MNHR	26.00	104,832
UNDEVELOPED DESIGN DETAILS ~20%				516,651
TOTAL SITE PREPARATION AND MOB/DEMOB				$3,099,000

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SS-7 MODIFIED IN-SITU SOLIDIFICATION AND SOIL COVER

LOCATION: SETTLING PONDS
BADGER ARMY AMMUNITION PLANT

ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SS-7 MODIFIED IN-SITU SOLIDIFICATION AND SOIL COVER
CONTAMINATED SOIL DELINEATION & TREATABILITY TESTNG

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
CONTAMINATED SOIL DELINEATION				
SAMPLE COLLECTION	400	HR	56.00	$22,400
ON-SITE ANALYSIS	60	DAY	2600.00	156,000
OFF-SITE CONFIRMATORY ANALYSIS	100	SMPL	60.00	6,000
UNDEVELOPED DESIGN DETAILS ~20%				36,600
TOTAL CONTAMINATED SOIL DELINEATION				$221,000
TREATABILITY TESTING				
BENCH SCALE	1	LS	15000.00	$15,000
PILOT SCALE	1	LS	50000.00	50,000
UNDEVELOPED DESIGN DETAILS ~20%				13,000
TOTAL TREATABILITY TESTING				$78,000

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SS-7 MODIFIED IN-SITU SOLIDIFICATION AND SOIL COVER

LOCATION: SETTLING PONDS
BADGER ARMY AMMUNITION PLANT

ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SS-7 MODIFIED IN-SITU SOLIDIFICATION AND SOIL COVER
EXCAVATE CONTAMINATED SOIL & BACKFILL

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
SOIL COVER				
BORROW STUDIES	1	LS	60000.00	$60,000
COMMON BORROW	889000	CY	4.00	3,556,000
SPREAD & COMPACT	889000	CY	2.00	1,778,000
TOP SOIL	67000	CY	10.00	670,000
SPREAD & COMPACT	67000	CY	2.00	134,000
SEED, FERTILIZE, MULCH	87	AC	2000.00	174,000
UNDEVELOPED DESIGN DETAILS ~20%				1,274,000
TOTAL SOIL COVER				$7,646,000

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SS-7 MODIFIED IN-SITU SOLIDIFICATION AND SOIL COVER

LOCATION: SETTLING PONDS
BADGER ARMY AMMUNITION PLANT

ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SS-7 MODIFIED IN-SITU SOLIDIFICATION AND SOIL COVER
IN-SITU SOLIDIFICATION & SURFACE WATER MANAGEM

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
IN-SITU SOLIDIFICATION	260750	CY	45.00	$11,733,750
UNDEVELOPED DESIGN DETAILS ~20%				2,347,250
TOTAL IN-SITU SOLIDIFICATION				$14,081,000
SOLIDIFICATION				
EXCAVATE CONTAMINATED AND PLACE IN STOCKPILE (232000 CY) (2 MON)				
BACKHOE & OPERATOR (4 EA)	160	DAY	2850.00	$456,000
DUMPTRAILER & DRIVER (40 EA)	1600	DAY	800.00	1,280,000
LABORER	1280	HR	30.00	38,400
DOZER & OPERATOR (4 EA)	160	DAY	1500.00	240,000
LOAD & PLACE FOR SOLIDIFICATION (6 MON)				
FRONT END LDR & OPER (2 EA)	260	DAY	1300.00	338,000
DUMPTRAILER & DRIVER (12 EA)	1560	DAY	800.00	1,248,000
LABORER	2080	HR	30.00	62,400
DOZER & OPERATOR (2 EA)	260	DAY	1500.00	390,000
SOLIDIFICATION (2 EA)	232000	CY	70.00	16,240,000
UNDEVELOPED DESIGN DETAILS ~20%				4,058,200
TOTAL SOLIDIFICATION				$24,351,000
SURFACE WATER MANAGEMENT				
EXCAVATE DITCH, CONSTRUCT BERM	17100	CY	3.00	$51,300
DITCH BACKFILL & COMPACT	17100	CY	3.00	51,300
UNDEVELOPED DESIGN DETAILS ~20%				20,400
TOTAL SURFACE WATER MANAGEMENT				$123,000

DATE:04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SS-7 MODIFIED IN-SITU SOLIDIFICATION AND SOIL COVER

LOCATION: SETTLING PONDS
BADGER ARMY AMMUNITION PLANT

ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SS-7 MODIFIED IN-SITU SOLIDIFICATION AND SOIL COVER
POST CLOSURE MAINTENANCE

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
ANNUAL COSTS				
ANNUAL INSPECTION & REPORT	8	HR	50.00	$400
GROUNDWATER SAMPLING & ANALYSIS	1	LS	161000.00	161,000
MAINTENANCE ITEMS OCCURING EVERY 5 YEARS				
SITE REVIEW	1	LS	10000.00	$10,000
		SUBTOTAL		$10,000
ANNUALIZED COST OF MAINTENANCE ITEMS OCCURING EVERY 5 YEARS				1,810
SUBTOTAL ANNUAL COSTS				$163,210
UNDEVELOPED DESIGN DETAILS ~20%				32,790
TOTAL ANNUAL POST CLOSURE MAINTENANCE COSTS				$196,000

APPENDIX G.2

MATERIAL USAGE

SETTLING PONDS AND SPOILS DISPOSAL AREA

PROJECT SSP-553	COMP. BY KHC	JOB NO. 685301
	CHK. BY [illegible]	DATE

QUANTITY SUMMARY

	SETTLING PONDS	cy DISPOSAL AREAS	FINAL CREDIT	TOTAL
COMMON BORROW (I+II)	1,042,587	169,644	8026 ~~3440~~	1,220,257 ~~1,215,000 cy~~
CLAY	216,187	47644	3822	268,000 cy
TOPSOIL	108,094	23822	1911	134,000 cy
DRAINAGE SAND	108094	23822	1911	134,000 cy
GEOMEMBRANE	324280 sy	71467 sy	5733	400,000 sy
GEOTEXTILE	324280 sy	71467	5733	400,000 sy

EX-SITU S/S

TOTAL VOLUME = 232,000 cy TO TREAT

FORM 00.01 REV. 4/81

ABB Environmental Services, Inc.

PROJECT	COMP. BY	JOB NO.
BADGER FS SSP-SSB CAP MATERIAL VOLUMES SETTLING PONDS, CREEK, DISPOSAL AREAS	KHL	6853-09
	CHK. BY	DATE
	[illegible]	8/1/94

1

SETTLING PONDS

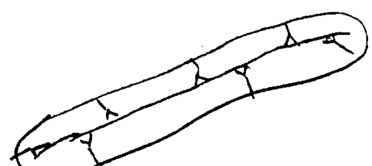
SURFACE AREAS:

SP-1 ≈ 480' x 2280'/43560 SF/AC ≅ 25 AC

SP-2 ≈ 480' x 480/43560 = 5 AC

SP-3 ≈ 360' WIDE x 3000'/43560 ≅ 25 AC

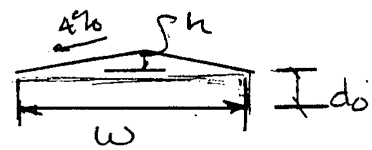
SP-4 ≈ 360' x 1440/43560 ≈ 12 AC



SOIL CAP VOLUMES

COMMON BORROW I: (BRING SITE TO GRADE)

- ASSUME 4% SLOPE ON 2 SIDES



$\Rightarrow h/w = 0.04 \quad h = .04w/2$

1) SP-1 $\quad w = 480$ FT $= h = .04\left(\frac{480}{2}\right) = 10$ FT

$d_{o_{SP-1}} = 4$ FT (FROM RI p 6-2)

$$V = \left[480(4) + \tfrac{1}{2}(2)\left(\tfrac{480}{2}\right)(10\text{ FT})\right] \times 2280\text{ LF} \times \frac{\text{CY}}{27\text{ CF}}$$

$V = \underline{364,800}$ CY

2) SP-2 $\quad w = 480$ FT $\quad h = .04\left(\frac{480}{2}\right) = 10$ FT

$d_{o_{SP-2}}$: ASSUME 4 FT DEEP (NOT NOTED IN RI TEXT)

$$V = \left[480(4) + \tfrac{1}{2}(2)\left(\tfrac{480}{2}\right)(10)\right] \times 480 \times \tfrac{1}{27} = \underline{76,800} \text{ CY}$$

PROJECT	COMP. BY	JOB NO.
BADGER SSP-SSB PONDS VOLUMES	KAL	6853-09
	CHK. BY LT	DATE 8/1/94

3) SP-2 $w = 360'$ d_0 : ASSUME 3FT DEEP

$h = .04\left(\frac{360'}{2}\right) = 7\text{ FT}$

$V = \left[360(3\text{FT DEEP}) + \frac{1}{2}(2)\left(\frac{360}{2}\right)(7)\right] \times 3000\text{ LF} \times \frac{1}{27} = \underline{\underline{260,000}}\text{ CY}$

4) SP-4 $W = 360'$ $L = 1440'$ $d_0 = 3\text{ FT}$ (RI TEXT p 6-2)

$h = .04\left(\frac{360}{2}\right) = 7\text{ FT}$

$V = \left[360(3') + 7\left(\frac{360}{2}\right)\right] \times 1440 \times \frac{1}{27} = \underline{\underline{124,800}}\text{ CY}$

COMMON BORROW
SUBTOTAL: $\boxed{8,26,400.\text{ CY}}$
(PONDS ONLY)

5) CLAY LAYER VOLUME

2-FT THICK

SP-1 : $25\text{AC} \times 43560 \times 2\text{FT THICK} / 27\text{CF/CY} = 80,667\text{ CY}$

SP-2 $5\text{AC} \times 43560 \times 2/27 = 16133\text{ CY}$

SP-3 $25\text{AC} \times 43560 \times 2/27 = 80667\text{ CY}$

SP-4 $12 \times 43560 \times 2/27 = \underline{38720\text{ CY}}$

SUBTOTAL 216,187 CY

- DRAINAGE SAND

1 FT THICK ∴ 1/2 CLAY VOLUME 216187/2

SUBTOTAL = $\underline{\underline{108094\text{ CY}}}$

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ABB Environmental Services, Inc.

PROJECT	COMP. BY	JOB NO.
BADGER SSP-SS3 PONDS ∀	KHL	6853-09
	CHK. BY	DATE
	LT	8/1/94

COMMON BORROW II

- USED BETWEEN TOPSOIL + DRAINAGE SAND
- SAME ∀ AS CLAY

SUBTOTAL (PONDS) = 216,187 CY

TOPSOIL

- 1 FT. THICK
- SAME ∀ AS DRAINAGE SAND = 108094 CY

GEOMEMBRANE

SP-1 = 25 AC
SP-2 = 5 AC
SP-3 = 25 AC
SP-4 = 12 AC

$67 \text{ ACRES} \times 43560 \text{ SF/AC} \times \frac{\text{SY}}{9 \text{ SF}} = 324,280 \text{ SY}$

GEOTEXTILE " " ⟶ 324,280 SY

SEEDING – 67 ACRES

PROJECT	COMP. BY	JOB NO.
BADGER SSP SS 3	KHL	6853-09
	CHK. BY	DATE
	[illegible]	8/1/94

SPOILS DISPOSAL PILES

SURFACE AREAS:

SS I = 200' W x 720 L = 144,000 SF (4 FT DEEP)

SS II = 200 W x 480 L = 96,000 SF (4 FT)

SS III = 120' W x 600' L = 72,000 SF (2 FT DEEP)

SS IV = 240' W x 840' L = 201,600 SF (2 FT)

SS V = 360 x 360 = 129,600 SF (2 FT)

TOTAL = 643,200 SF

TOPSOIL

1 FT (634,200 SF)/27 = 23822 cy

COMMON BORROW 2

2 FT THICK i.e. 2 X TOPSOIL V = 47644 cy

DRAINAGE SAND

1 FT THICK ⇒ SAME V AS TOPSOIL = 23822 cy

CLAY LAYER

- 2 FT THICK → 47644 cy

GEOTEXTILE

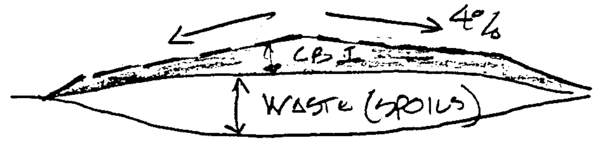
643,200 SF / 9 → 71,467 SY

GEOMEMBRANE

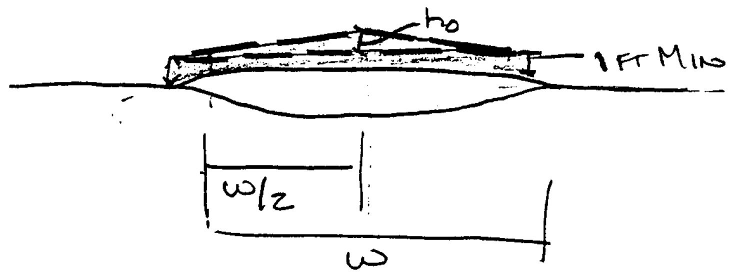
" " → 71467 SY

PROJECT	COMP. BY	JOB NO.
BADGER FS SSP-SS3	KAC	685309
	CHK. BY	DATE
		8/1/94

COMMON BORROW I



- ASSUME FILL PIT
  + 4% TO DRAIN



1) SS I

$w = 200'$
$L = 720'$

$h_0 = .04\left(200/2\right) = 4$ FT

$V = \left(4'(200) + \tfrac{1}{2}(2)(4')\left(\tfrac{200}{2}\right)\right] 720 \times 1/27 = 32{,}000$ cy

2) SS II $\quad w = 200 \quad L = 480$

$h_0 = .04(200/2) = 4'$

$V = \left(4'(200) + \cancel{\tfrac{1}{2}(2)}(4)\left(\tfrac{200}{2}\right)\right] \times 480 \times 1/27 = 21{,}333$ cy

3) SS III $\quad w = 120 \quad L = 600$

$h_0 = .04\left(\tfrac{120}{2}\right) \sim 2.5'$

$V = \left(2(120) + 2.5\left(120/2\right) \times 1/2 \times 2\right] \times 600 \times 1/27 = 8{,}667$ cy

4) SS IV $\quad w = 240 \quad L = 840$

$h_0 = .04\left(240/2\right) \sim 5$ FT

$V = \left(2'(240) + 5'\left(240/2\right)\right) 840 \times 1/27 = 33{,}600$ cy

PROJECT	COMP. BY	JOB NO.
BADGER SSP-SS3	KAL	6853-09
	CHK. BY	DATE
	NX	8/1/94

5) SSV $W = 360'$ $L = 360'$

$h_0 = .04(360/2) = 7$ FT

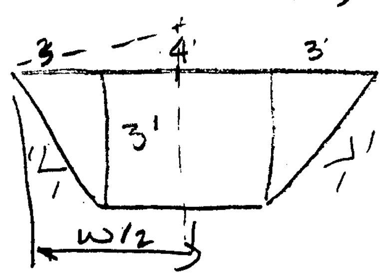
$V = (2'(360\,LF) + 7(360/2))\,360 \times 1/27 = \underline{26,400}$ cy

SUBTOTAL CBI : $\boxed{122,000 \text{ cy}}$

FINAL CREEK VOLUMES

- ASSUME 10 FT WIDE, 3 FT DEEP (DRAFT FS 7/93)
- 4% SLOPE

$L \doteq 5160$ FT (SCALED FROM FIG 12-2)



$A_x = 1.3 \times 3' + 3 \times 4' = \cancel{17}$ SF
21

COMMON BORROW I: (BRING TO GRADE)

$V = [21\,SF + .04(10/2) \times (10/2)]\,5160 \times 1/27 = \cancel{3748}$ 4204 cy

Clay: $2\,FT\,(10\,FT)(\sim 5160) \times 1/27 = \underline{3822}$ cy

DRAINAGE SAND

1 FT THICK = 1/2 CLAY   1911 cy

COMMON BORROW II:

2 FT THICK ⟶ 3822 cy

TOPSOIL 1 FT ⟶ 1911 cy

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PROJECT	COMP. BY	JOB NO.
BADGER FS SSP-SS3	KAL	6853-09
	CHK. BY	DATE
	LA	8/1/94

GEOMEMBRANE

10 FT X 5160 / 9 SF/SY = 5733 SY

GEOTEXTILE ⟶ 5733 SY

PROJECT	COMP. BY	JOB NO.
SSP-SS7	KHL	685309
	CHK. BY	DATE
	LV	8/1/94

MODIFIED INSITU S/S $\overline{w}$ SOIL COVER

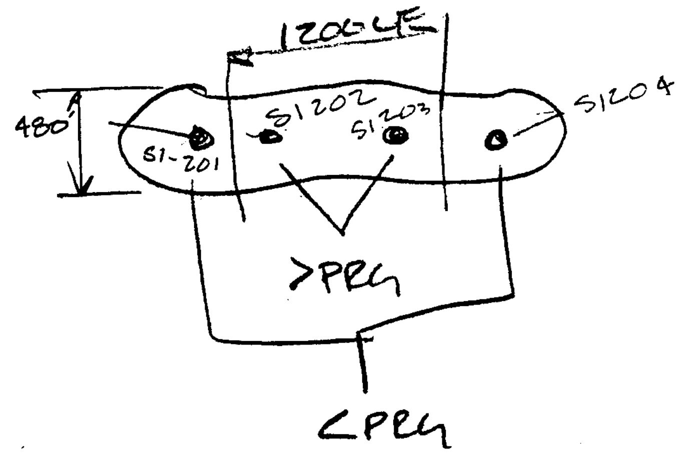
I. SP-1 STABILIZATION

ASSUME REMOVE TO LIMITS OF 1/2 BETWEEN DATA ABOVE PRGS TO DATA BELOW PRGS

- 10 FT DEEP

V = 10 FT (1200 LF) * 480 x 1/27

$\boxed{= 213,000 \text{ CY}}$



II. DISPOSAL AREAS

- ASSUME STABILIZE + REMOVE TO 1 FT LAYER OF SPOILS.
- DETERMINE VOLUME OF SPOILS TO TREAT PER FOOT OF DEPTH FOR EACH DISPOSAL PIT.

→ FROM PG 4

SS-1	A = 144,000 SF	V = 144,000 CF :	5333 CY
SS-2	A = 96,000 SF	V = 96000 CF =	3555 CY
SS-3	A = 72,000 SF	= 72000 CF =	2667 CY
SS-4	A = 201,600	=	7467 CY
		SUBTOT	19,000 CY

TOTAL = 213,000 + 19,000 = $\boxed{232,000 \text{ CY}}$

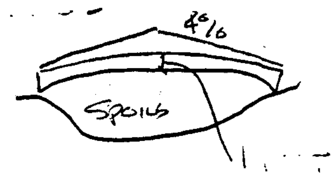
PROJECT	COMP. BY	JOB NO.
BADGER FS SSP - SS3	KHL	6853-09
	CHK. BY	DATE
	NT	8/1/94

MATERIAL QUANTITY ASSUMPTIONS

① USE FIGURE 12-3 TO SCALE DIMENSIONS OF PONDS + DISPOSAL AREAS

② ASSUME PONDS, CREEK, AND DISPOSAL PITS WILL BE FILLED WITH COMMON BORROW AND GRADED TO 4%.

③ ASSUME CREEK IS 10 FT WIDE AND 3 FT DEEP



④ ASSUME AVERAGE DEPTHS OF PONDS AS NOTED IN SECTION 6 OF RI.

⑤

APPENDIX H

SOUTHERN OFF-POST AREA

APPENDIX H.1

MATERIAL USAGE: GROUNDWATER ALTERNATIVES

SOUTHERN OFF-POST AREA

PROJECT BAAP - FS SOPA Approximate Pressure Drop through Vapor phase Carbon Adsorbers	COMP. BY CW	JOB NO. 06853-09
	CHK. BY	DATE 7/20/94

see enclosed information provided by Karl Kraus 7/20/94 from Calgon carbon Corp.

Know: vessel Diameter = 10 ft
Bed Depth = 3.4 ft
Full vessel = 8000 lbs

Volume vessel = $\pi (5)^2 (3.4) = 267.\ ft^3$

Packing Density $\dfrac{8000\ lb}{267\ ft^3} = 30\ lb/ft^3$ ⇐ dense pack

Flow per vessel = 6000 cfm Air

$Q = VA$

velocity $= V = \dfrac{Q}{A} = \dfrac{6000\ ft^3/min}{\pi (5)^2} = 76.4\ ft/min$

use Pressure Drop curve ⇒ 3.5" H_2O/ft Bed

∴ total Pressure Drop/vessel = $(3.5)(3.4) \approx 12''\ H_2O$ /vessel

PROJECT Badger FS – SoPA Approximate Headloss through Aqueous Phase Carbon Adsorbers	COMP. BY Cw	JOB NO. 06853-09
	CHK. BY	DATE 7/20/94

& Size appropriate pumps

- See Enclosed information Provided by Karl Krauss 7/20/94 from calgon Corp.

- From the enclosed graph @ 1000 gall/min a specific psi could not be read directly for units in series.

  I approximated ≃ 50 psi from the graph to be Conservative. which is well below the pressure rating.

$$\therefore \ TDH = 50 \text{ psi} \times \frac{2.31 \text{ ft } H_2O}{1 \text{ psi}} = 116 \text{ ft}$$ for clean conditions

add ~~≈~~ 50% to be conservative

$\Rightarrow$ 170 ft

I. Groundwater Extraction Scenario 1

* 3000 gpm
* 120 ft

Horse Power Requirement (assume 80% eff.)

$$\frac{170 \text{ ft} \times 3000 \text{ gpm}}{0.80 \quad 3960} = 160 \text{ HP}$$

Probably Goulds Model 3175 – 1780 RPM (160 HP,
8 x 10 -14 6 vane
(See enclosed)
efficiency curve

II. Groundwater Extraction Scenario 2

6000 gpm

∴ Need two of the above pumps

III. Groundwater Extraction Scenario 3

12,000 gpm

∴ need Four of the above pumps

FORM 00.01 REV. 4/81

ABB Environmental Services, Inc.

PROJECT	COMP. BY	JOB NO.
Badger Final FS — SOPA Estimate Treatment system Influent concentrations for 3 different pumping scenarios for the Off-Post Area	CW	06853-09
	CHK. BY	DATE 7/4/94

Scenario 1:

Extraction wells located between, PBM-90-02D and Wisconsin River;

* Assume contaminant concentrations are not increasing at the base boundary and that there are no biochemical transformations, retardation or dispersive effects between the base boundary and extraction wells:
  - use 1992 RI Data only

1. Take a depth-averaged concentration for each contaminant at the Base Boundary:

note: used max conc between Round I + II

Well Series	SPN-89-01C S1101 & S1133	SPN-89-02 A,B,C SPN-91-02D	SPN-89-03 B,C SPN-91-03D, S1147	SPN-89-04 B,C S1148, SPN-91-04D	S1102 S1103 S1152 A,B
CCL_4	ND	13.5	42.3	10.2	1.83
TRCLE	ND	ND	0.98	1.92	0.11
$CHCL_3$	0.58	1.5	4.4	1.82	0.40

* Assume plume at Base Boundary is 1625 ft wide

2. Compute weighted Average concentration for each contaminant as would be realized in the effluent of the combined extraction wells. used Area under the curve produced by graphing depth-averaged concentration by cross sectional distance.

CCL_4 (see fig 1) 4.55 ug/L ⇒ Assume 10.0 ug/L

TRCLE Assume 1.0 ug/L

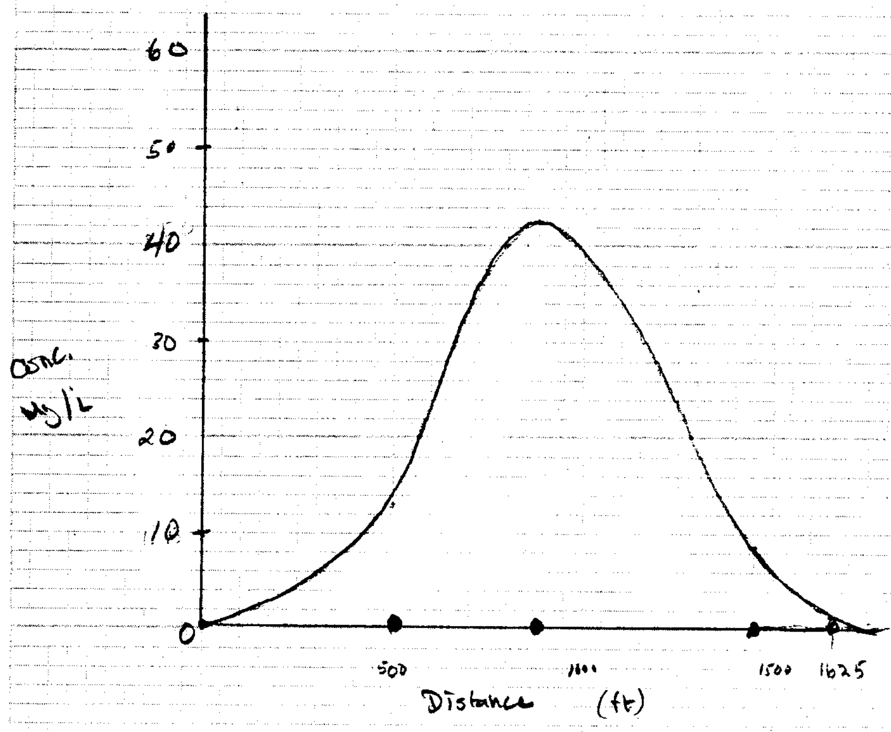
, to be conservative

$CHCL_3$ Assume 2.0 ug/L

②

PROJECT Badger - FS - SOPA Estimate Treatment System Influent Concentrations for 3 different pumping scenarios for the off post area	COMP. BY Cw	JOB NO. 06853-09
	CHK. BY	DATE 7/5/94

Figure 1 - CCL4



Area = 7400 ug/L • ft

∴ weighted Avg. = 4.55

1" = 500 Ft

 ③

PROJECT Badger – FS SOPA Estimate Treatment System Influent Conc's for 3 Δ pumping scenarios for the off-post area	COMP. BY CW	JOB NO. 06853-09
	CHK. BY	DATE 7/5/94

Scenario 2:

Row 1 extraction wells located adjacent to County Z rd.

Row 2 extraction wells located between PBM-90-02D and Wisconsin river

* Use same assumptions as in Scenario 1

1. For Row 1 extraction wells use weighted average concentrations as found in Scenario 1

2. For Row 2 extraction wells compute weighted Average concentrations for each contaminant using wells located near County Z.

a. Depth – Average conc.

well series	SWN-91-01 B,C,D	SWN-91-02 C,D	SWN-91-03 B,C,D,E	SWN-91-04 C,D
CCl_4	ND	ND	4.22	ND
TRCLE	ND	ND	0.18	ND
$CHCl_3$	ND	0.22	0.33	ND

3. Compute weighted Average - ug/L
- Since wells are ≈ Equidistant & equal pump rates from wells - add conc's and divide by 4

CCl_4 1.1 ⇒ Assume 5.0 ug/L - to be conservative
TRCLE 0.05 ⇒ Assume 1.0 ug/L
$CHCl_3$ 0.14 ⇒ Assume 1.0 ug/L

4. Estimate combined influent concentrations from Row 1 and Row 2 Extraction wells,

≈ CCl_4 7.5 ug/L
TRCLE 2.0 ug/L
$CHCl_3$ 1.5 ug/L

PROJECT Badger - FS SOPA Estimate Treatment System Influent conc. for 3 Δ pumping scenarios for the off post area	COMP. BY Cw	JOB NO. 06853-09
	CHK. BY	DATE 7/5/94

Scenario 3: 4 Rows of Extraction wells

Row 1 as described in Scenario 2

Row 2 as described in scenario 2

Row 3 Extraction wells located Equidistant between the base boundary and county Z rd.

Row 4 Extraction wells located Equidistant between County Z rd. and Row 2 extraction wells

1. For Row 3 Extraction wells use weighted averages found in scenario 1:
   CCl_4 10.0 ug/L
   TRCE 1.0 ug/L
   CCl_3 2.0 ug/L
2. For Row 4 Extraction wells use weighted averages found for Row 2 in Scenario 2:
   CCl_4 5.0 ug/L
   TRCE 1.0 ug/L
   CCl_3 1.0 ug/L
3. For Row 1 extraction wells Assume approximately half the depth-averaged concentrations, and the Calculated weighted average between Base Boundary + County Z wells
   CCl_4 6.0 ug/L
   TRCE 1.0 ug/L
   $CHCl_3$ 1.0 ug/L
4. For Row 2 extraction wells assume approximately half the depth-averaged concentrations between the County Z wells and PBM-90-02 B,C,D, and calculated weighted averages:
   CCl_4 2.0 ug/L
   TRCE 1.0 ug/L
   $CHCl_3$ 1.0 ug/L

PROJECT Badger FS SOPA Estimate Treatment System influent concs for 3 D pumping scenarios for the off-post area	COMP. BY CL	JOB NO. 06853-09
	CHK. BY	DATE 7/5/94

Scenario 3 continued...

5. Estimate combined influent concentrations from all four extraction well rows:

≈ CCl_4 6.0 ug/L
TRCLE 1.0 ug/L
$CHCl_3$ 1.0 ug/L

PROJECT BAAP FS - SOPA Extraction Scenarios for 5, 10, 20, 40 year Cleanup of Southern off-Post Area	COMP. BY DRP CHK. BY modified checked	JOB NO. 6853-14 DATE 7-21-94

Batch Flushing model

Purpose: Estimate groundwater extraction scenarios for 5, 10, 20, 40 year cleanup of Southern Off-Post Area contaminant plume.

Assumptions: ① All contaminated groundwater at the base boundary, south of the Propellant Burning Ground (PBG), is being intercepted by a row of extraction wells (Figure 1). I.e., plume is cut off at the southern base boundary.

② TRCLE maximum concentration is 100 ug/L. TRCLE is least mobile contaminant (K_{oc} = 126 mL/g)

③ Aquifer characteristics:

Soil bulk density (ρ_b) = 2.0 g/mL
f_{oc} = 0.0005 (see attached calculation)
K = 340 ft/day (Woodard-Clyde, 1994)
Porosity (n) = 0.3
Gradient (average) = 0.0020 (Figure 2)
= 0.0018 South. Bdy → County Z
= 0.0025 County Z → Wisconsin R.

④ Concentrations of TRCLE indicated on Figure 1 are based on data from the IRDMIS available April 12, 1994. Data from private wells not included.

PROJECT BAAP FS - SOPA foc Estimate from Known Contaminant Transport Distances	COMP. BY DRP	JOB NO. 6853-14
	CHK. BY modified checked by CW	DATE 7-21-94

Batch Flushing model

The BAAP RI Report indicates f_{oc} is on the order of 0.003.

Estimate of f_{oc} from Contaminant Transport Distances:

CCL4 has been detected as far south as PBM-90-02D, and may have been transported as far south as the Wisconsin River (along groundwater flow lines).

Based on historical information, CCL4 was first disposed of at the Propellant Burning Ground (PBG) as early as 1945.

Distance traveled by CCL4 : ~17,000 feet (time ≅ 50 years)

Groundwater flow velocity is on the order of 700 ft/yr based on a K of 340 ft/day from Dec. 1993 aquifer test.

Since 1945, groundwater has flowed approx. 35,000 feet, CCL4 may have been discharged to the Wisconsin R.

The distance traveled by TRCLE is known to be between monitoring wells SWN-91-03B and PBM-90-02D, or approximately 14,000 feet.

Based on historical information, TRCLE was disposed of at the PBG as early as 1965.

Distance traveled by TRCLE : ~14,000 feet (time ≅ 29 years)

Since 1965, groundwater has flowed approx. 20,300 ft, further than TRCLE has been detected.

$$V_c = V_x / [1 + (\rho_b/\theta) K_{oc} * f_{oc}]$$

V_c = vel. of solute front where sol. conc. = 0.5 of orig. conc.
= 14,000 ft/29 years = 480 ft/yr

V_x = avg. linear groundwater flow vel.
= 20,300 ft/29 years = 700 ft/yr.

ρ_b = dry bulk density of soil = 2.0 g/mL

θ = volumetric moisture content of soil = 0.3

K_{oc} = 126 mL/g for TRCLE

Solving the equation above for f_{oc}:

$$f_{oc} = 0.0005$$

PROJECT BAAP-FS SOPA Batch Flushing model	COMP. BY DRP	JOB NO. 06853-14
	CHK. BY modified + checked by CWW	DATE 7/21/94

Pore Volume Estimates:

Using the USEPA batch-flushing model, the number of pore volumes required to lower the dissolved concentration from an initial value C_i to a target level C_s is:

$$PV = -\frac{1}{\ln\left[1+\left(n/(\rho_b \cdot K_{oc} \cdot f_{oc})\right)\right]} \ln\left(\frac{C_s}{C_i}\right)$$

The maximum CCL4 concentration at the southern base boundary is 100 ug/L; the target remediation goal is 0.50 ug/L (WDNR Preventative Action Limit). for Both CCL4 and TRCLE

TRCLE Koc values will be used for all calculations because it has a higher Koc value than other COCs (CCL4, CCL3 ...), and therefore provides a more conservative estimate of clean-up times. CCL4 concentrations will be used as C_i to be conservative

Pumping Rates for Extraction Well Rows:

Based on estimates from 1993 aquifer test (Woodard-Clyde), the flow rate necessary to capture/intercept the plume at the southern base boundary is 3000 gpm.

For the purposes of these estimates, it is assumed that flow rates for any transect across the contaminant plume will be 3000 gpm.

PROJECT BAAP - FS SOPA Batch Flushing model	COMP. BY DRP	JOB NO. 06853-14
	CHK. BY modified + checked by CHW	DATE 7/21/94

Extraction Well Scenario 1:

Extraction well(s) located between PBM-90-02D and the Wisconsin River; Extraction Well Row #1.

Q necessary to intercept plume: 3000 gpm

Estimated groundwater travel time from southern base boundary to Extraction Well Row #1:

$$V = Ki/n = (340\,ft/day)(0.0020)/0.3$$
$$= 2.3\,ft/day$$

$d = 12{,}000$ feet (from southern base boundary to Extr. Well Row #1)

$$t = d/v = (11{,}750\,ft)/(2.3\,ft/day)$$
$$= 5{,}110\,days$$

Pore Volume / Flush Estimate (based on USEPA batch-flushing model): $C_s = 0.5\,ug/L$; $C_i = 100\,ug/L$

$$PV = -\frac{1}{\ln[1+(0.3/(2.0*126*0.0005))]}\ln\left(\frac{0.5}{100}\right)$$
$$= 4.3\ \text{flushes}$$

Estimated Cleanup Time:

$$(5{,}110\,days)(4.3\ \text{flushes})\left(\frac{1\ year}{365\ days}\right) = 61\ years$$

PROJECT BAAP - FS - SOPA Batch Flushing model	COMP. BY DRP	JOB NO. 06853-14
	CHK. BY notified and checked by CW	DATE 7/21/94

Extraction Well Scenario #2:

Extraction Well Rows #1 and #2 (see Figure 1)

$Q_{Row\#1}$: 3000 gpm

$Q_{Row\#2}$: 3000 gpm

Calculations for Extraction Well Row #2:

$V = Ki/n = (340\ ft/day)(0.0018)/0.3$
$= 2.0\ ft/day$

$d = 5500$ feet (from south bdy. to Extr. Well Row #2)

$t = d/V = (5750\ ft)/(2.0\ ft/day)$
$= 2{,}875\ days$

Pore Volume/Flush Estimate: $C_s = 0.5\ \mu g/L$, $C_i = 100\ \mu g/L$

$$PV = -\frac{1}{\ln[1+(0.3/(2.0*126*0.0005))]} \ln\left(\frac{0.5}{100}\right) = 4.3 \text{ flushes}$$

Est. Cleanup Time: (2875 days)(4.3 flushes) = 34 years

Calculations for Extraction Well Row #1:

$V = ki/n = (340\ ft/day)(0.0025)/0.3 = 2.8\ ft/day$

$d = 5500$ feet (distance between Extr. Well Rows #1 and #2)

$t = d/V = (6000\ ft)/(2.8\ ft/day) = 2{,}140\ days$

Pore Volume/Flush Estimate: $C_s = 0.5\ \mu g/L$, $C_i = 20\ \mu g/L$

$$PV = -\frac{1}{\ln[1+(0.3/(2.0*126*0.0005))]} \ln\left(\frac{0.5}{20}\right) = 3.0 \text{ flushes}$$

Est. Cleanup Time: (2140 days)(3.0 flushes) = 18 years

PROJECT	COMP. BY	JOB NO.
BAAP - FS SOPA Batch Flushing model	DRP	06853-14
	CHK. BY modified checked by DM	DATE 7/21/94

Extraction Well Scenario 3 :

Extraction Well Rows #1, #2, #3, #4

$Q_{Row1} = Q_{Row2} = Q_{Row3} = Q_{Row4} = 3000$ gpm

Calculations for Extraction Well Row #4:

$V = Ki/n = (340\ ft/day)(0.0018)/0.3 = 2.0\ ft/day$

$d = 2500$ feet

$t = d/V = (2500\ ft)/(2.0\ ft/day) = 1250$ days

Pore Volume / Flush Estimate: $C_s = 0.5\ ug/L$, $C_i = 100\ ug/L$

PV = 4.3 flushes (see Extr. Well Scenario 2)

Est. Cleanup Time: (1250 days)(4.3 flushes) = 15 years

Calculations for Extraction Well Row #2:

$V = Ki/n = (340\ ft/day)(0.0018)/0.3 = 2.0\ ft/day$

$d = 3250$ feet

$t = d/V = (3250\ ft)/(2.0\ ft/day) = 1625$ days

Pore Volume / Flush Estimate: $C_s = 0.5\ ug/L$, $C_i = 50\ ug/L$

$$PV = -\frac{1}{\ln[1+(0.3/(2.0*126*0.0005))]}\ln\left(\frac{0.5}{50}\right) = 3.8 \text{ flushes}$$

Est. Cleanup Time: (1625 days)(3.8 flushes) = 17 years

Calculations for Extraction Well Row #3:

$V = Ki/n = (340\ ft/day)(0.0025)/0.3 = 2.8\ ft/day$

$d = 3000$ feet

$t = d/V = (3000\ ft)/(2.8\ ft/day) = 1070$ days

Pore Volume / Flush Estimate: $C_s = 0.5\ ug/L$, $C_i = 20\ ug/L$

$$PV = -\frac{1}{\ln[1+(0.3/(2.0*126*0.0005))]}\ln\left(\frac{0.5}{20}\right) = 3.0 \text{ flushes}$$

Est. Cleanup Time: (1070 days)(3.0 flushes) = 9 years

PROJECT BAAP - FS SOPA Batch Flushing Model	COMP. BY DRP	JOB NO. 06853-14
	CHK. BY	DATE 7/21/94

Calculations for Extraction Well Row #1:

$V = Ki/n = (340\ ft/day)(0.0025)/0.3 = 2.8\ ft/day$

$d = 3000$ feet

$t = d/V = (3000ft)/(2.8\ ft/day) = 1070$ days

Pore Volume / Flush Estimate : $C_s = 0.5\ \mu g/L$, $C_i = 15\ \mu g/L$

$$PV = -\frac{1}{\ln[1+(0.3/(2.0*126*0.0005))]} \ln\left(\frac{0.5}{15}\right) = 2.8 \text{ flushes}$$

Est. Cleanup Time: (1070 days)(2.8 flushes) = 8 years

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ABB Environmental Services, Inc.

PROJECT BAAP FS Minimal Action - Estimate of natural clean up time - USEPA Batch Flushing model	COMP. BY CW	JOB NO. 06853-09
	CHK. BY	DATE 8/2/94

* See Previous Calculations (7/21/94) for Groundwater extraction Scenario's 1, 2 and 3 for format and Assumptions for USEPA Batch Flushing Model

See enclosed spreadsheet for Calculations + Results

fa. 2 of 2

USEPA BATCH FLUSHING MODEL

PROJECT: BADGER FINAL FS - SOPA
06853-09

This model is applicable for estimating aquifer cleanup times

INPUT PARAMETERS		
INITIAL MAX CONC (ug/L) =	100	
TARGET CONC(ug/L) =	0.5	
COMPOUND Koc =	126	
Foc =	0.0005	*Fraction of organic carbon in aquifer media
BULK DENSITY (Pb) =	2	* Usually around 2.5
HYDRAULIC CONDUCTIVITY(ft/day) =	340	
HYDRAULIC GRADIENT(feet/foot) =	0.002	
POROSITY =	0.3	
CONTAMINANT TRAVEL DISTANCE(ft) =	12500	Distance btw. base boundary and Wisconsin River

OUTPUTS		
GROUNDWATER VELOCITY(ft/day) =	2.266667	
TIME FOR CONTAMINANT TRAVEL(years) =	15.10878	
PORE VOLUME FLUSHES NEEDED =	4.349452	
ESTIMATED CLEANUP TIME (years) =	**65.71493**	≈ 66.

PREPARED BY C. VAUGHAN

PROJECT Badger FS - SOPA Size of Influent and Effluent Equilization TANKS	COMP. BY LWR	JOB NO. 06853-09
	CHK. BY	DATE 7/20/94

A. Groundwater Extraction Scenario #1

→ 3000 gpm

Assume 10 min Residence time is sufficient

$\therefore V = QT$

$V = (3000)(10\ min) = 30{,}000\ gall$

$30{,}000\ gall \times \frac{1\ ft^3}{7.48\ gall} = 4011\ ft^3$

$\approx 4000\ ft^3$

– Assume 10 ft Deep & a square tank

$\approx \therefore$ Dimensions For Both tanks 20 ft x 20 ft x 10 ft deep

Specifications: use 12" concrete on walls + Bottom
use 8" concrete top

B. Groundwater Extraction Scenario #2

→ 6000 gpm

– Same Assumptions as above

≈ Dimensions 65 ft x 65 ft x 10 ft deep

C. Groundwater Extraction Scenario #3

→ 12,000 gpm

– same assumptions as above

≈ Dimensions 40 ft by 40 ft by 10 ft deep

PROJECT Badger FS - SOPA Size pumps for the 3 scenarios for Influent Equil. Basin - through Air stripper	COMP. BY Cw CHK. BY	JOB NO. 06853-09 DATE 7/19/94

I. Groundwater Extraction Scenario 1

* 3000 gpm
* Tower Hieght to water intake ≈ 40 ft - say 60 ft to be conservative

Horse power Requirement (Assume 80% eff)

$$\frac{60\,ft \times 3000\,gpm}{0.80 \times 3960} \simeq 60\,HP$$

Probaby Goulds Model 3175 - 1180 RPM (60 HP)
8x10-18H, 2 vane
(see enclosed)

II. Groundwater Extraction Scenario 2

6000 gpm

∴ Need 2 pumps of above type

III. Groundwater Extraction Scenario 3

12,000 gpm

∴ Need 4 pumps of the above type

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ABB Environmental Services, Inc.

PROJECT Badger FS - SOPA Size Effluent Gravity Discharge Pipe	COMP. BY	JOB NO. 06853-09
	CHK. BY	DATE 7/23/94

I. Groundwater Extraction Scenario 1 - 3000 gpm

Use Chezy-Manning Equation for Pipe Flowing ½ Full (to be conservative)

Pipe Diameter $= D = 1.731 \left(\frac{nQ}{\sqrt{s}}\right)^{3/8}$

where n = manning's number (≈0.014 for HDPE)
s = slope
Q = flow ft³/sec

$$S = \frac{\Delta \text{ elev.}}{\text{Length Discharge pipe}} = \frac{60 \text{ ft}}{4000 \text{ ft}} = 0.015$$

$$Q(\text{ft}^3/\text{sec}) = 3000 \frac{\text{gall}}{\text{min}} \times \frac{1 \text{ min}}{60 \text{ sec}} \times \frac{1 \text{ ft}^3}{7.48 \text{ gall}} = 6.68 \text{ ft}^3/\text{sec}$$

$$D = 1.731 \left(\frac{(0.014)(6.68)}{\sqrt{0.015}}\right)^{3/8 \; 0.375} = 1.56 \text{ ft}$$

∴ to be conservative use 2 ft Dia (24")

II Groundwater Extraction Scenario 2 - 6000 gpm

use same eqn. & assumptions as above

$$D = 1.731 \left(\frac{(0.014)(13.4)}{\sqrt{0.015}}\right)^{3/8} = 2.03 \text{ ft}$$

∴ to be conservative use 36"

$$Q = 6000 \text{ gpm} = 13.4 \text{ ft}^3/\text{sec}$$

III. Groundwater Extraction Scenario 3 - 12,000 gpm

$$D = 1.731 \left(\frac{(0.014)(26.74)}{\sqrt{0.015}}\right)^{3/8} = 2.63 \text{ ft}$$

to be conservative use 48"

$$Q = 12000 \text{ gpm} = 26.74 \text{ ft}/\text{sec}$$

Note: use HPDE if available

PROJECT	COMP. BY	JOB NO.
Badger FS - SOPA Size Air Heater for Air Stripper and Consider energy requirements	CMV CHK. BY	06853-09 DATE 7/18/94

* I used 90% Design for on-post treatment facility Air stripper Heater specifications (...) prepared by Woodward-Clyde (Woodward-Clyde, 1994b)

1. Assume Air temp leaving the Air stripper is approx. equal to the incoming water temp. ≈ 60°F

2. Vapor phase GAC manufacturers prefer to have air @ ≈ 40% Relative Humidity (RH)

   Assume Temp leaving Blower ≈ 85°F

   $$\therefore \%RH = \frac{Vp@60°F}{Vp@85°F} = \frac{0.5218\ "Hg}{1.2139\ "Hg} = 43\%\ RH \checkmark$$

3. Consider an A/W ratio of 45:1, a water flow rate of 3000 gpm and an air flow rate of 18,000 cfm

   Assume air entering blower = 55°F

   ∴ Air density = 0.0771 lb/ft³ (Woodward-Clyde 1994b)

   $\dot{m}$ = Air Flow Rate (mass) = 18,000 ft³/min × 0.0771 lb/ft³ = 1388. lb/min

   = 83300 lb/hr ≈ 85000 lb/hr

4. Heat Input Required:

   Specific heat of air in temp range 0-100°F = 0.25 BTU/°F = C

   $\Delta T = 85°F - 55°F = 30°F$

   Heat Transfer Rate = $Q = \dot{m}\, c_p \Delta T$ = (85000 lb/hr)(0.25 BTU/°F)(30°F)

   = 637,500 BTU/hr

PROJECT Badger FS - SOPA Size Air Heater for air strippers and Consider energy requirements	COMP. BY [illegible]	JOB NO. 06853-09
	CHK. BY	DATE 7/18/94

Assume 10% Heat loss

$$(637{,}500 \text{ BTU/hr})(1.1) = 701250$$

$$\approx 700{,}000 \text{ BTU/hr}$$

5. Propane gas properties: mol. wt = 44.09 lb
mo. vol = 372.7 ft^3

Heating properties = 2522 BTU/ft^3

$$\text{Propane Heating value} = \left(2522 \frac{\text{BTU}}{\text{ft}^3}\right)\left(\frac{372.7 \text{ ft}^3}{44.09 \text{ lb}}\right) = 21{,}319 \text{ BTU/lb}$$

$\approx 21{,}000$ BTU/lb

$$\text{Propane Requirement} = \frac{700{,}000 \text{ BTU/hr}}{21{,}000 \text{ BTU/lb}} = 33 \text{ lb/hr}$$

= 792 lb/day

$\boxed{\approx 800 \text{ lb/Day}}$

6. Size Propane tanks:

(LPG) Liquid propane density = 4.24 lb/gall

$$\text{LPG required} = \frac{800 \text{ lb/day}}{4.24 \text{ lb/gall}} = 189 \text{ gall/day} \approx 200 \text{ gall/day}$$

≈ 200 gall/day

For 5,000 gall capacity. assume can only fill to 80%

∴ 4,000 gall $\approx$ 20 days.

tank size

∴ TWO 5,000 gall tanks are proposed

7. Propane cost per year: Surburban propane - ¢50/gall

$$200 \text{ gall/day} \times \frac{365 \text{ day}}{\text{year}} \times \frac{\$0.5}{1 \text{ gall}} = \$36{,}500./\text{year}$$

Heating cost per tower

* Assume tank rental is at nominal cost

PROJECT Badger FS - SOYA	COMP. BY CW	JOB NO. 06853-09
Size of Heater for air stripper and consider energy requirements	CHK. BY	DATE 7/18/94

8. Size "Heater":

Using the Info. Provided in 208 Design by woodward-clyde
see Hastings spec's Provided

Need SBD-218-1902

Called Lee Ball Inc., cambellsport, WI
which is a Hastings heater dealer

His quote is enclosed.

18,000 CFM @ 1.25 ; 1902 MBH Gas
15 HP motor

PROJECT BAAP FS TDH Calcs: SOPA GW extraction scenarios Extraction wells to Treatment fac.	COMP. BY CW CHK. BY	JOB NO. 6853-09 DATE 7/12/94

A. Scenario #1

Using Hazen-Williams formula

$$f = 0.2083 \left(\frac{100}{c}\right)^{1.85} \frac{q^{1.85}}{d^{4.8655}}$$

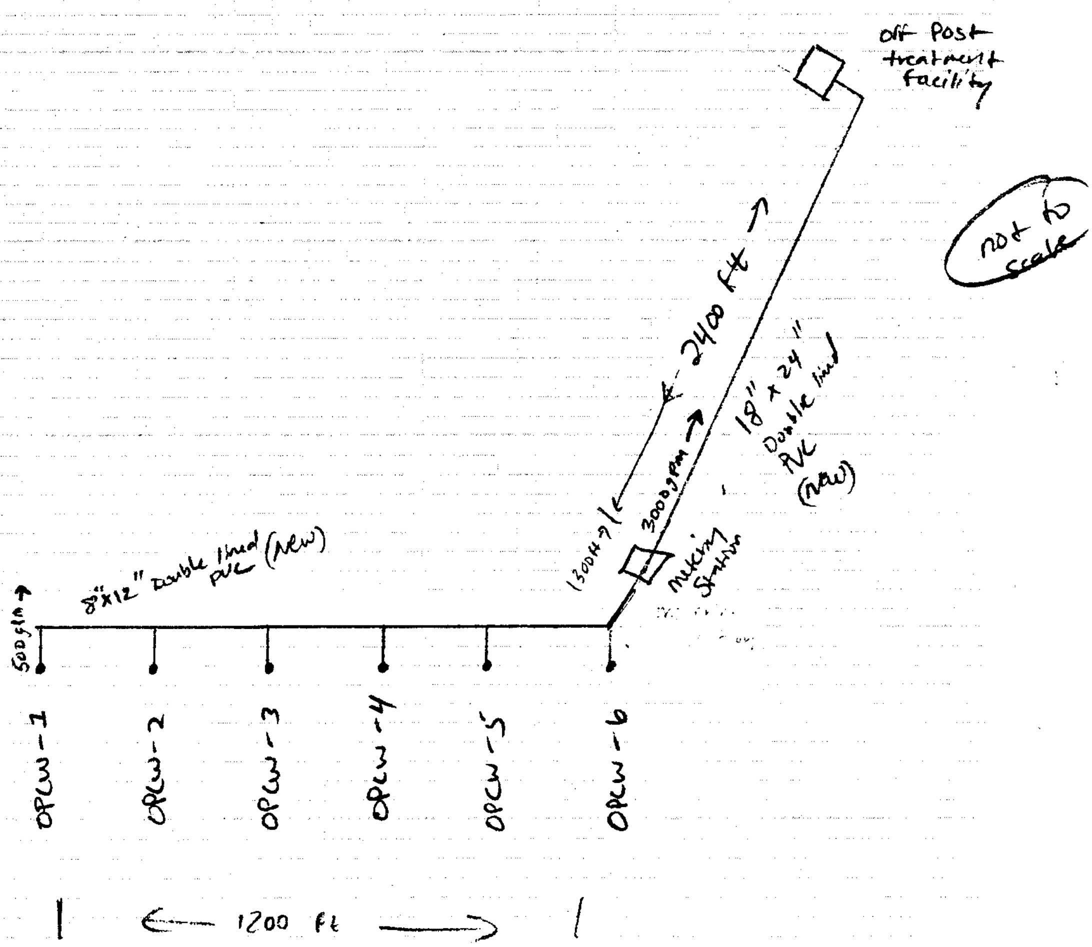
Where

f = friction head per 100 ft of pipe (feet)

q = Flow (gpm)

C = Constant for surface Roughness
Use 130 for PVC

d = ID of pipe (inches)



PROJECT BAAP FS TDH Calcs: SOPA GW ext. Scenarios: Extraction wells to treatment fac.	COMP. BY [illegible]	JOB NO. 6853-09
	CHK. BY	DATE 7/12/94

Worst case ⇒ OPCW-6 Extraction well
TDH

I. Dynamic Head Losses

(a) Assume 6" DOP pipe (schd 80) : LINEAR LENGTH + EQUIVALENT

200' (Pump to well head)
+ 4.' (Gate valve) 6" Ref: Camerons Hydraulic Data Handbook
+ 30' (90° Elbow) 6"

234.'

$$f = 0.2083 \left(\frac{100}{130}\right)^{1.85} \frac{(375)^{1.85}}{(6)^{4.8655}} = 1.21 \text{ ft}/100 \text{ ft pipe}$$

∴ For 234 ft pipe

$$f_{total} = 1.21 \times 2.34 = 2.84$$
$$\approx 5 \text{ ft}$$

(b) Assume 8" Double lined (8"x 12") Pipe to metering station from OPCW-6
LINEAR LENGTH + EQUIVALENT

1500' (well to metering station, 8")
80' (2 x 90° ELBOWS, 8")

1660

$$f = 0.2083 \left(\frac{100}{130}\right)^{1.85} \frac{(375)^{1.85}}{(8)^{4.8655}} = 0.3 \text{ ft}/100 \text{ ft}$$

$$f_{total} = 0.3 \times 16.6 = 4.98$$
$$\approx 5 \text{ ft}$$

PROJECT BAAP FS TDH calcs: SOPA GW Ext. Scenarios Exhaction wells to treatment fac.	COMP. BY CAV	JOB NO. 6853-09
	CHK. BY	DATE 7/12/94

(c) Assume 18" (Double lined 18" x 24") pipe from metering station to Treatment Facility

LINEAR LENGTH + EQUIVALENT

2420' (metering station → Treatment fac.)

270' (3x 90° ELBOW) 90 x 3

2-670'

$f = 0.006/100$ ft

$f_{total} = 1.60 \approx 2.0$ ft

(d) Headloss due to self cleaning strainer.

max needed → 25 psi (Ref. 90% Design Woodward-Clyde)

Ref. John M.

≈ 25 psi Drop across filter

∴ Equiv. ft Headloss = 25 psi × $\frac{2.31 \text{ ft } H_2O}{1 \text{ psi}}$ = 57.8 ft

≈ 58 ft

II. Static Head

- Assume water level @ 740 ft @ DPCW-6
- Assume a drawdown of ≈ 15 ft

Thus water level @ Ext. well = 740 − 15 = 725

- Assume Treatment Facility is at an elevation of ≈ 840 ft

∴ Total Static Head = 115 ft

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PROJECT BAAP FS TDH Calcs: SOPA GW ext. scenarios Extraction wells to treatment Fac.	COMP. BY Cw	JOB NO.
	CHK. BY	DATE 7/12/94

III. Calculate TDH needed for extraction well

total Dynamic Headloss + static Head

= ⓐ + ⓑ + ⓒ + ⓓ + static Head

= 5 + 5 + 2 + 58 + 115

= 185

≃ 200 ft

∴ Extraction well pumps must deliver 500 gpm @ 200 ft TDH

Hydraulic Power Required = $\frac{500\text{gpm} \times 200\text{ft}}{3960} \approx 25\text{hp}$

From the efficiency curve, Submersible Pumps are ≃ 66% efficient

∴ $\frac{25}{0.66} = 38.3$ ∴ a 40 HP pump is required

- see performance curves

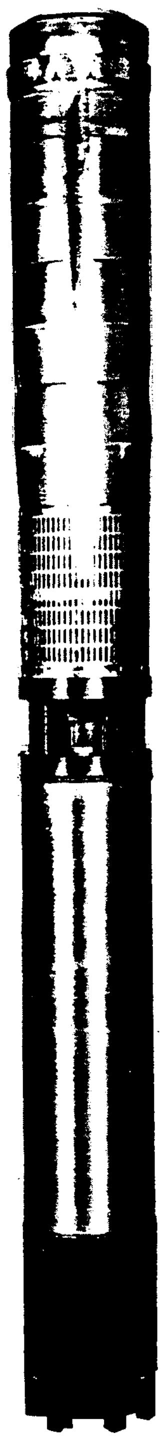
* The Grundfos model 600S400-3 or equivalent is recomended for extraction wells: OPCW-1, -2, -3, -4, -5, -6

MODEL
600S

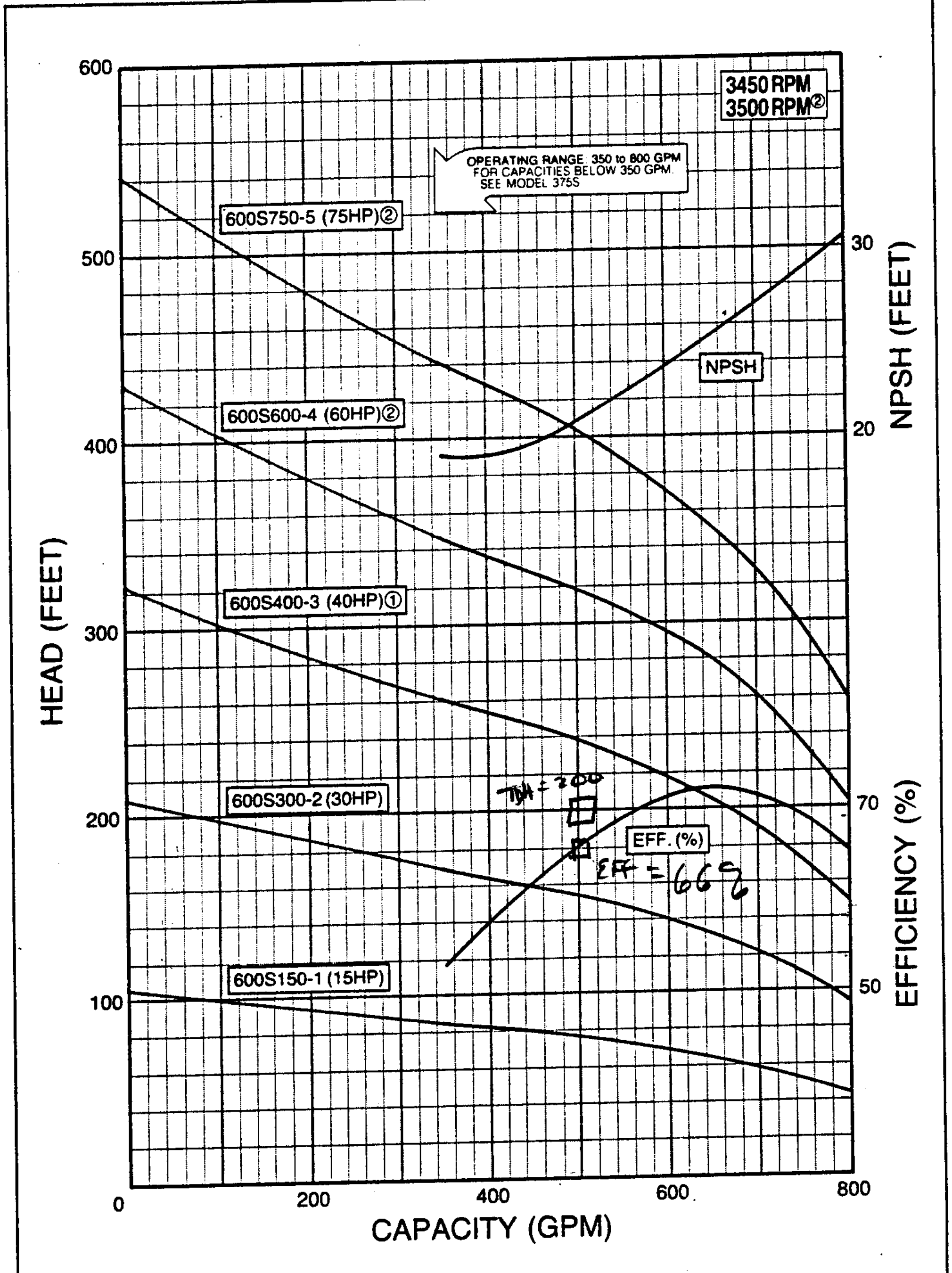
600 GPM

GRUNDFOS

FLOW RANGE
350 to 800 GPM
PUMP OUTLET
5" NPT



PERFORMANCE CURVES



DIMENSIONS AND WEIGHTS

MODEL NO.	HP	MIN. WELL SIZE (INCHES)	LENGTH (INCHES)	MAX. WIDTH (INCHES)	APPROX. UNIT SHIPPING WT. (LBS.)
600S150-1	15	10	52 1/4	9 1/8	207
600S300-2	30	10	66 3/8	9 1/8	250
600S400-3	40①	10	79 1/4	9 1/8	341
600S600-4	60②	10	87 3/4	9 1/4	567
600S750-5	75②	10	99	9 1/4	635

NOTES: ① 6-inch motor standard; 8-inch motor optional.
② 8-inch motor.
Specifications are subject to change without notice.
See Deep Set models for higher head.

PROJECT BAAP FS TDA Calcs; SOPA GW extraction Scenarios; Ext. wells to treatment Fac.	COMP. BY Cm	JOB NO. 6853-09
	CHK. BY	DATE 7/12/94

B. Scenario #2 and #3

* In Scenario #2 a second row of extraction wells are located along County Z road

max elev. head from OPCW-7 is ≈ 95 ft to treat fac. along w/ the additive filter head drop of 46 ft (for 3000gpm)

- The same Ground water extraction pumps that were calculated for scenario #1 are recomended.

Note: the same flow is required (500 gpm) from each of the six wells from Row 2.

* In Scenario #3 a third and fourth row of extraction wells are added. Row #3 is ≈ between Rows 1 and 2 and Row #4 is ≈ between the base boundary and Row #2.

- worste case elev. head for Row 3 and 4 are ≈ 95 and 85 ft to the treatment facility, repectively. The additive filter head drop for 3000gpm (for each ext. well Row) is 46 ft.
  - The Same Groundwater extraction Pumps that were calculated for scenario #1 are recomended for extraction wells for Rows 3 and 4.

Note: The same flow is required (500 gpm) from each of the extraction wells

PROJECT BAAP FS - SOPA Electrical Service Requirement	COMP. BY CW	JOB NO. 06853-09
	CHK. BY	DATE 7/25/94

I. GW Extraction Scenario 1 - Air stripping

6	Extraction wells (40 HP)	=	240 HP
1	Influent Transfer pump (60 HP)	=	60 HP
1	Blower (75 HP)	=	75 HP
8	motor starters (5 HP)	=	40
			415 HP

$415 HP \times \frac{0.746\ KW}{HP} \approx 310\ KW$

ADD ≈ 100 KW For Building light + power → 410 KW ← we for O&M

Double for uncertainty ~ 820 KW ← use to size incoming power

II. GW Extraction Scenario 2 - Air stripping

12	Extraction wells (40 HP)	480
2	Influent Transfer Pumps (60 HP)	120
2	Blowers (75 HP)	150
10	Motor starters (5 HP)	50
		800

$800\ HP \times \frac{0.746\ KW}{HP} \approx 600\ KW$

ADD ≈ 150 KW for Building, Light, Power, etc. → 750 KW

Double for uncertainty ~1300 KW

III. GW Extraction Scenario 3 - Air stripping

24	Extraction wells (40 HP)	960
4	Influent Transfer pumps (60 HP)	240
4	Blowers (75 HP)	300
12	Motor starters (5 HP)	60
		1560 ⇒ 1164 K

ADD ≈ 300 KW for Building, Light, Power, etc. → 1460 KW

Double for uncertainty ≈ 2900 KW

pg. 2 of 2

PROJECT BAAP FS - SofA Electrical Service requirement	COMP. BY	JOB NO. 06853-09
	CHK. BY	DATE 7/25/94

IV Groundwater Extraction Scenario 1 - Carbon adsorption

6	Extraction wells (40 HP)	240
1	Influent Transfer pump (160 HP)	160
8	motor starters (5 HP)	40
		440 HP

$440 \text{ HP} \times \frac{0.746 \text{ kW}}{1 \text{ HP}} \simeq 328. \text{ kW}$

Add 86 kW for Bld light, power ≈ 410

Double for uncertainty 820 kW

V Groundwater Extraction Scenario 2 - Carbon adsorption

12	extraction wells (40 HP)	480
2	Influent transfer pumps (160 HP)	320
10	motor starters (5 HP)	50
		850 HP

$850 \text{ HP} \times \frac{0.746 \text{ kW}}{\text{HP}} \approx 634 \text{ kW}$

Add 143 kW for Bld light + power → 780

Double for uncertainty ⇒ 1560 kW

VI Groundwater Extraction Scenario 3 - Carbon Adsorption

24	Extraction wells (40 HP)	960
4	Influent Transfer pumps (160 HP)	640
12	motor starters (5 HP)	60
		1660 HP

$1660 \text{ HP} \times \frac{0.746 \text{ kW}}{\text{HP}} = 1238 \text{ kW}$

Add 279 kW for Bld light + power → 1500

Double for uncertainty 3000

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ABB Environmental Services, Inc.

APPENDIX H.2

COSTS: GROUNDWATER ALTERNATIVES

SOUTHERN OFF-POST AREA

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION GW-1 MINIMAL ACTION
LOCATION: SOUTHERN OFF-POST AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION GW-1 MINIMAL ACTION COST SUMMARY TABLE DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
DIRECT COST OF OPTION GW-1 MINIMAL ACTION				
EDUCATION PLAN PREPARATION				$50,000
TOTAL DIRECT COST OF OPTION GW-1 MINIMAL ACTION				$50,000
INDIRECT COST OF OPTION GW-1 MINIMAL ACTION				
HEALTH AND SAFETY			0.00%	$0
LEGAL, ADMIN, PERMITTING			0.00%	0
ENGINEERING			0.00%	0
SERVICES DURING CONSTRUCTION			0.00%	0
TOTAL INDIRECT COST OF OPTION GW-1 MINIMAL ACTION				$0
TOTAL CAPITAL (DIRECT + INDIRECT) COST				$50,000
OPERATING AND MAINTENANCE COSTS				
TOTAL COST REPLACEMENT WELLS				$22,000
TOTAL PRESENT WORTH OF REPLACEMENT WELLS IN YEAR 16 @ 5%				$10,000
TOTAL ANNUAL OPERATING AND MAINTENANCE COSTS				$184,000
TOTAL PRESENT WORTH OF ANNUAL O&M COSTS (5% FOR THIRTY YEARS)				$2,829,000
TOTAL PRESENT WORTH OF OPERATING AND MAINTENANCE COSTS				$2,839,000
TOTAL COST OF OPTION GW-1 MINIMAL ACTION				$2,889,000

DATE:04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION GW-1 MINIMAL ACTION
LOCATION: SOUTHERN OFF-POST AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION GW-1 MINIMAL ACTION

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
EDUCATION PLAN PREPARATION	1	LS	50000.00	$50,000
OPERATING & MAINTENANCE COSTS (WELLS REPLACED IN YEARS 16, 32, 4				
REPLACEMENT WELLS	2	EA	10000.00	$20,000
CONTINGENCY ~10%				2,000
TOTAL COST REPLACEMENT WELLS				$22,000
ANNUAL OPERATING & MAINTENANCE COSTS				
GROUNDWATER SAMPLING & ANNALYSIS	1	LS	160540.00	$160,540
EDUCATIONAL PROGRAMS	1	LS	5000.00	5,000
FIVE YEAR SITE REVIEW @ $10,000 EVERY FIVE YEARS	1	LS	1809.75	1,810
CONTINGENCY ~10%				16,650
TOTAL ANNUAL OPERATING & MAINTENANCE COSTS				$184,000

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION SOPA-GW2 AIR STRIPPING -
GROUNDWATER EXTRACTION SCENARIO 1 JOB # 6853-09
LOCATION: SOUTHERN OFF-POST AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SOPA-GW2 A/S + GWE 1
COST SUMMARY TABLE

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
DIRECT COST OF OPTION SOPA-GW2 A/S + GWE 1				
SITE PREPARATION AND MOB/DEMOB				$399,000
GROUNDWATER EXTRACTION PUMPS & PIPING				2,042,000
TREATMENT PLANT BUILDING				437,000
TREATMENT PLANT PROCESS EQUIPMENT				618,000
ELECTRICAL & INSTRUMENTATION				1,014,000
GRAVITY DISCHARGE				346,000
EDUCATION PLAN PREPARATION				50,000
TOTAL DIRECT COST OF OPTION SOPA-GW2 A/S + GWE 1				$4,906,000
INDIRECT COST OF OPTION SOPA-GW2 A/S + GWE 1				
HEALTH AND SAFETY			5.00%	$245,000
LEGAL, ADMIN, PERMITTING			5.00%	245,000
ENGINEERING			10.00%	491,000
SERVICES DURING CONSTRUCTION			10.00%	491,000
TOTAL INDIRECT COST OF OPTION SOPA-GW2 A/S + GWE 1				$1,472,000
TOTAL CAPITAL (DIRECT + INDIRECT) COST				$6,378,000
OPERATING AND MAINTENANCE COSTS				
TOTAL ANNUAL OPERATING AND MAINTENANCE COSTS				$729,000
TOTAL PRESENT WORTH OF ANNUAL O&M COSTS (5% FOR SIXTY-ONE YEARS)				$13,837,000
TOTAL PRESENT WORTH OF OPERATING AND MAINTENANCE COSTS				$13,837,000
TOTAL COST OF OPTION SOPA-GW2 A/S + GWE 1				$20,215,000

DATE:04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SOPA-GW2 AIR STRIPPING -
GROUNDWATER EXTRACTION SCENARIO 1
LOCATION: SOUTHERN OFF-POST AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SOPA-GW2 A/S + GWE 1
SITE PREPARATION AND MOB/DEMOB

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
EQUIPMENT (IN OR OUT)				
FRONT END LOADER	2	EA	520.00	$1,040
DUMP TRUCKS	4	EA	260.00	1,040
BACKHOE	2	EA	950.00	1,900
WELL DRILLER	1	LS	10000.00	10,000
OFFICE TRAILER	8	MON	155.00	1,240
STORAGE TRAILER (2 EA)	16	MON	155.00	2,480
TRAILER SET-UP & DELIVERY, REMOVAL	3	EA	310.00	930
TOILET (2 EA*8 MON/EA)	70	WK	25.00	1,750
WATER CLR (2EA*8MON/EA)	70	WK	25.00	1,750
WATER (70 WK * 5 DAY/WK)	350	DAY	15.00	5,250
TELEPHONE SERVICE	8	MON	520.00	4,160
ELECTRICAL HOOK-UP	1	LS	2500.00	2,500
ELECTRICAL POWER	8	MON	300.00	2,400
PICK-UP (2 EA * 8 MON/EA)	16	MON	1035.00	16,560
OFFICE EQUIPMENT	8	MON	1035.00	8,280
PUMPS, TOOLS MINOR EQUIPMENT	1	LS	5000.00	5,000
VEHICLE PARKING AREA				
CLEAR & GRUB LIGHT VEGETATION	0.5	AC	3825.00	1,913
GRADE	825	CY	2.00	1,650
GRAVEL - 12" THICK	2420	SY	3.50	8,470
DECON PAD	1	LS	10000.00	10,000
LABORER (2 MEN*10 DAY/MAN*8 HR/DAY)	160	MNHR	30.50	4,880
CARPENTER (2 MEN*10 DAY/MAN*8 HR/DAY)	160	MNHR	39.00	6,240
ELECTRICIAN (2 MEN*10 DAY/MAN*8 HR/DAY	160	MNHR	42.50	6,800
SITE SUPERINTENDANT (8 MON*210 HR/MON)	1680	MNHR	62.25	104,580
FOREMAN (8 MON * 210 HR/MON)	1680	MNHR	51.75	86,940
CLERK/TYPIST (8 MON * 168 HR/MON)	1344	MNHR	26.00	34,944
UNDEVELOPED DESIGN DETAILS ~20%				66,304
TOTAL SITE PREPARATION AND MOB/DEMOB				$399,000

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SOPA-GW2 AIR STRIPPING -
GROUNDWATER EXTRACTION SCENARIO 1
LOCATION: SOUTHERN OFF-POST AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SOPA-GW2 A/S + GWE 1 GROUNDWATER EXTRACTION PUMPS & PIPING DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
EXTRACTION WELLS	6	EA	69600.00	$417,600
EXTRACTION PUMPS	6	EA	25000.00	150,000
EXTRACTION WELL PIPING				
8" HDPE WITH 12" CONTAINMENT	5300	LF	80.00	424,000
18" HDPE WITH 24" CONTAINMEN	2400	LF	265.00	636,000
METERING STATION (INCL LP GAS TANKS)				
FOUNDATION - FTG & SLAB	25	CY	200.00	5,000
WALLS	25	CY	300.00	7,500
8" CONCRETE BLOCK WALLS	640	SF	7.50	4,800
ROOF	240	SF	10.00	2,400
DOOR - 3'x7'	1	EA	750.00	750
HVAC	240	SF	5.00	1,200
LP HEATER	1	LS	1000.00	1,000
ELECTRICAL LIGHTS & POWER	240	SF	7.50	1,800
POWER PANEL	1	EA	2500.00	2,500
TRANSFORMER, 30 KVA	1	EA	2200.00	2,200
PIPE, VALVES & FITTINGS	1	LS	25000.00	25,000
4" FLOW METER	6	EA	2500.00	15,000
2" AIR RELEASE VALVE	6	EA	250.00	1,500
LAND EASEMENTS	3	AC	1200.00	3,600
UNDEVELOPED DESIGN DETAILS ~20%				340,150
TOTAL GROUNDWATER EXTRACTION PUMPS & PIPING				$2,042,000

DATE:04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SOPA-GW2 AIR STRIPPING -
GROUNDWATER EXTRACTION SCENARIO 1
LOCATION: SOUTHERN OFF-POST AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SOPA-GW2 A/S + GWE 1 TREATMENT PLANT BUILDING DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
PUMP PIT & EQUALIZATION BASINS				
EXCAVATION	2500	CY	2.00	$5,000
BACKFILL	1500	CY	3.50	5,250
SPOIL	1000	CY	2.00	2,000
CONCRETE				
SLAB	100	CY	150.00	15,000
WALLS	200	CY	250.00	50,000
ELEVATED SLAB	20	CY	350.00	7,000
HANDRAIL	64	LF	20.00	1,280
LADDER	16	VLF	50.00	800
FLOOR HATCH - 6x8	4	EA	3000.00	12,000
3x3	1	EA	800.00	800
LIGHTS & MISC POWER	400	SF	7.50	3,000
HVAC	400	SF	5.00	2,000
PROCESS AREA				
PRE-ENGINEERED BUILDING, 16' EAVE 20' RIDGE HT, 52'W x 88'L	4576	SF	22.50	102,960
DOORS - 3'x7'	5	EA	750.00	3,750
6'x7'	2	EA	1050.00	2,100
ROLLING 12'x12'	1	EA	2750.00	2,750
WINDOWS - 4'x4'	5	EA	850.00	4,250
FLOOR TRENCH CONCRETE	3	CY	250.00	750
GRATING	56	SF	25.00	1,400
INTERIOR PARTITION	936	SF	7.00	6,552
LIGHTS & MISC POWER	4576	SF	6.00	27,456
HVAC	4576	SF	5.00	22,880
PAINTING	2000	SF	1.00	2,000
PAVING	500	SY	12.50	6,250
TOTAL THIS SHEET				$287,228

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SOPA-GW2 AIR STRIPPING -
GROUNDWATER EXTRACTION SCENARIO 1
LOCATION: SOUTHERN OFF-POST AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SOPA-GW2 A/S + GWE 1 TREATMENT PLANT BUILDING DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
TOTAL PAGE 4				$287,228
OFFICE AREA				
SLAB FLOOR, 8' MIN CLG, SHED TYPE	1456	SF	20.00	29,120
INTERIOR PARTITIONS	496	SF	7.00	3,472
FINISHES				
OFFICE	504	SF	4.50	2,268
CLOSET	36	SF	8.00	288
TOILET	108	SF	20.00	2,160
ELECTRICAL ROOM	560	SF	3.50	1,960
ELECTRICAL WORK				
OFFICE	504	SF	10.00	5,040
CLOSET	36	SF	6.00	216
TOILET	108	SF	7.50	810
ELECTRICAL ROOM	560	SF	6.00	3,360
HVAC				
OFFICE	504	SF	7.50	3,780
CLOSET	36	SF	5.00	180
TOILET	108	SF	7.50	810
ELECTRICAL ROOM	560	SF	5.00	2,800
DOORS - 3'x7'	2	EA	750.00	1,500
WINDOWS - 4'x4'	4	EA	850.00	3,400
LAND	0.5	AC	1200.00	600
POTABLE WATER SUPPLY	1	LS	10000.00	10,000
SEPTIC SYSTEM	1	LS	5000.00	5,000
UNDEVELOPED DESIGN DETAILS ~20%				73,008
TOTAL TREATMENT PLANT BUILDING				$437,000

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION SOPA-GW2 AIR STRIPPING -
GROUNDWATER EXTRACTION SCENARIO 1
JOB # 6853-09

LOCATION: SOUTHERN OFF-POST AREA
BADGER ARMY AMMUNITION PLANT

ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SOPA-GW2 A/S + GWE 1
TREATMENT PLANT PROCESS EQUIPMENT

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
SELF CLEANING STRAINER	1	EA	20000.00	$20,000
INFLUENT PUMPS, 3000 GPM, 60 HP	2	EA	15000.00	30,000
AIR STRIPPING TOWER, BLOWER & DUCTWORK	1	LS	240000.00	240,000
OFF GAS HEATER & DUCTWORK	1	EA	10000.00	10,000
VAPOR PHASE CARBON UNITS	3	EA	45000.00	135,000
VENT STACK	1	LS	25000.00	25,000
18" DIA PVC PIPE, VALVES, FITTINGS	100	LF	300.00	30,000
AIR COMPRESSOR	1	LS	10000.00	10,000
AIR PIPE, FITTINGS, VALVES	300	LF	25.00	7,500
WATER PIPE, FITTINGS, VALVES	300	LF	25.00	7,500

UNDEVELOPED DESIGN DETAILS ~20%	103,000
TOTAL TREATMENT PLANT PROCESS EQUIPMENT	$618,000

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION SOPA-GW2 AIR STRIPPING -
GROUNDWATER EXTRACTION SCENARIO 1
JOB # 6853-09

LOCATION: SOUTHERN OFF-POST AREA
BADGER ARMY AMMUNITION PLANT

ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SOPA-GW2 A/S + GWE 1 ELECTRICAL & INSTRUMENTATION DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
GROUNDWATER EXTRACTION				
UNDERGROUND DUCT, 4x3 CND, 14"x18"	3300	LF	100.00	330,000
POWER CABLE TO PUMPS, 4-2/0	20000	LF	10.00	200,000
POWER CABLE TO METERING STATION 4-1/0	2500	LF	8.00	20,000
INSTRUMENTATION CABLE				
TO WELL LEVEL SENSOR	20000	LF	1.00	20,000
TO METER STATION FLOW METERS	15000	LF	1.00	15,000
PROCESS EQUIPMENT				
ELECTRICAL UTILITY SERVICE	1	LS	75000.00	75,000
MOTOR CONTROL CENTER	1	LS	40000.00	40,000
150 KVA XFMR	1	EA	5250.00	5,250
225A, 277/480V 42 CKT PANEL BOARD	1	EA	3500.00	3,500
225A, 120/208V 42 CKT PANEL BOARD	1	EA	1925.00	1,925
LARGE POWER CIRCUITS				
4-#3, 1.25" C	100	LF	13.25	1,325
4-#4, 1.25" C	400	LF	12.65	5,060
6-500MCM, 4" C PER PHASE	100	LF	215.00	21,500
4-#2, 1.25" C	450	LF	14.00	6,300
4-#12, 3/4" C	1200	LF	7.50	9,000
INSTRUMENTATION				
CONTROL PANEL	1	LS	50000.00	50,000
PROCESS AREA INSTRUMENTATION	10	EA	2500.00	25,000
WIRING	2500	LF	6.50	16,250
UNDEVELOPED DESIGN DETAILS ~20%				168,890
TOTAL ELECTRICAL & INSTRUMENTATION				$1,014,000

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SOPA-GW2 AIR STRIPPING -
GROUNDWATER EXTRACTION SCENARIO 1
LOCATION: SOUTHERN OFF-POST AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SOPA-GW2 A/S + GWE 1 GRAVITY DISCHARGE DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
24" DIA RCP	4000	LF	65.00	$260,000
MANHOLE	5	EA	3000.00	15,000
DISCHARGE HEADWALL	1	LS	10000.00	10,000
LAND EASEMENT	3	AC	1200.00	3,600
UNDEVELOPED DESIGN DETAILS ~20%				57,400
TOTAL GRAVITY DISCHARGE				$346,000
EDUCATION PLAN PREPARATION	1	LS	50000.00	$50,000

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION SOPA-GW2 AIR STRIPPING -
GROUNDWATER EXTRACTION SCENARIO 1
JOB # 6853-09
LOCATION: SOUTHERN OFF-POST AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SOPA-GW2 A/S + GWE 1 ANNUAL OPERATION & MAINTENANCE DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
PUMPING & BLOWER ELECTRICAL	2700000	KWHR	0.04	$108,000
BUILDING ELECTRICAL	876000	KWHR	0.04	35,040
OFF GAS HEATING (200 GAL PROPANE/DAY)	73000	GAL	0.5	36,500
GROUNDWATER MONITORING	1	LS	160540.00	160,540
EDUCATIONAL PROGRAMS	1	LS	5000.00	5,000
INFLUENT SAMPLING - VOLATILES	48	SMPL	275.00	13,200
INORGANICS	48	SMPL	163.00	7,824
EFFLUENT SAMPLING - VOLATILES	24	SMPL	275.00	6,600
INORGANICS	24	SMPL	163.00	3,912
AIR SAMPLING - VOLATILES	4	EA	150.00	600
PARTICULATES	4	EA	50.00	200
LABOR COSTS - 1.5 MAN/YEAR	3120	HR	30.00	93,600
MAINTENANCE COSTS	5.00%	LS	3710000.00	185,500
CARBON REPLACEMENT EACH 10 YEARS ($18,000 PER UNIT FOR 3 UNITS)	0.079504	LS	54000.00	4,293
FIVE YEAR SITE REVIEW @ $10,000 EVERY FIVE YEARS	0.180974	LS	10000.00	1,810
CONTINGENCY ~10%				66,381
TOTAL ANNUAL OPERATING & MAINTENANCE COSTS				$729,000

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SOPA-GW2 AIR STRIPPING -
GROUNDWATER EXTRACTION SCENARIO 2
LOCATION: SOUTHERN OFF-POST AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SOPA-GW2 A/S + GWE 2
COST SUMMARY TABLE

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
DIRECT COST OF OPTION SOPA-GW2 A/S + GWE 2				
SITE PREPARATION AND MOB/DEMOB				$480,000
GROUNDWATER EXTRACTION PUMPS & PIPING				3,863,000
TREATMENT PLANT BUILDING				671,000
TREATMENT PLANT PROCESS EQUIPMENT				1,236,000
ELECTRICAL & INSTRUMENTATION				1,611,000
GRAVITY DISCHARGE				670,000
EDUCATION PLAN PREPARATION				50,000
TOTAL DIRECT COST OF OPTION SOPA-GW2 A/S + GWE 2				$8,581,000
INDIRECT COST OF OPTION SOPA-GW2 A/S + GWE 2				
HEALTH AND SAFETY			5.00%	$429,000
LEGAL, ADMIN, PERMITTING			5.00%	429,000
ENGINEERING			10.00%	858,000
SERVICES DURING CONSTRUCTION			10.00%	858,000
TOTAL INDIRECT COST OF OPTION SOPA-GW2 A/S + GWE 2				$2,574,000
TOTAL CAPITAL (DIRECT + INDIRECT) COST				$11,155,000
OPERATING AND MAINTENANCE COSTS				
TOTAL ANNUAL OPERATING AND MAINTENANCE COSTS				$1,138,000
TOTAL PRESENT WORTH OF ANNUAL O&M COSTS (5% FOR THIRTY-FOUR YEARS)				$18,428,000
TOTAL PRESENT WORTH OF OPERATING AND MAINTENANCE COSTS				$18,428,000
TOTAL COST OF OPTION SOPA-GW2 A/S + GWE 2				$29,583,000

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SOPA-GW2 AIR STRIPPING -
GROUNDWATER EXTRACTION SCENARIO 2
LOCATION: SOUTHERN OFF-POST AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SOPA-GW2 A/S + GWE 2 SITE PREPARATION AND MOB/DEMOB DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
EQUIPMENT (IN OR OUT)				
FRONT END LOADER	2	EA	520.00	$1,040
DUMP TRUCKS	4	EA	260.00	1,040
BACKHOE	2	EA	950.00	1,900
WELL DRILLER	1	LS	10000.00	10,000
OFFICE TRAILER	10	MON	155.00	1,550
STORAGE TRAILER (2 EA)	20	MON	155.00	3,100
TRAILER SET-UP & DELIVERY, REMOVAL	3	EA	310.00	930
TOILET (2 EA*10 MON/EA)	86	WK	25.00	2,150
WATER CLR (2EA*10MON/EA)	86	WK	25.00	2,150
WATER (86 WK * 5 DAY/WK)	430	DAY	15.00	6,450
TELEPHONE SERVICE	10	MON	520.00	5,200
ELECTRICAL HOOK-UP	1	LS	2500.00	2,500
ELECTRICAL POWER	10	MON	300.00	3,000
PICK-UP (2 EA * 10 MON/EA)	20	MON	1035.00	20,700
OFFICE EQUIPMENT	10	MON	1035.00	10,350
PUMPS, TOOLS MINOR EQUIPMENT	1	LS	5000.00	5,000
VEHICLE PARKING AREA				
CLEAR & GRUB LIGHT VEGETATION	0.5	AC	3825.00	1,913
GRADE	825	CY	2.00	1,650
GRAVEL - 12" THICK	2420	SY	3.50	8,470
DECON PAD	1	LS	10000.00	10,000
LABORER (2 MEN*10 DAY/MAN*8 HR/DAY)	160	MNHR	30.50	4,880
CARPENTER (2 MEN*10 DAY/MAN*8 HR/DAY)	160	MNHR	39.00	6,240
ELECTRICIAN (2 MEN*10 DAY/MAN*8 HR/DAY	160	MNHR	42.50	6,800
SITE SUPERINTENDANT (10 MON*210 HR/MON	2100	MNHR	62.25	130,725
FOREMAN (10 MON * 210 HR/MON)	2100	MNHR	51.75	108,675
CLERK/TYPIST (10 MON * 168 HR/MON)	1680	MNHR	26.00	43,680
UNDEVELOPED DESIGN DETAILS ~20%				79,908
TOTAL SITE PREPARATION AND MOB/DEMOB				$480,000

DATE:04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SOPA-GW2 AIR STRIPPING -
GROUNDWATER EXTRACTION SCENARIO 2
LOCATION: SOUTHERN OFF-POST AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SOPA-GW2 A/S + GWE 2
GROUNDWATER EXTRACTION PUMPS & PIPING

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
EXTRACTION WELLS	12	EA	69600.00	$835,200
EXTRACTION PUMPS	12	EA	25000.00	300,000
EXTRACTION WELL PIPING				
8" HDPE WITH 12" CONTAINMENT	12600	LF	80.00	1,008,000
18" HDPE WITH 24" CONTAINMEN	3500	LF	265.00	927,500
METERING STATION (INCL LP GAS TANKS) - 2 REQ'D				
FOUNDATION - FTG & SLAB	25	CY	200.00	$5,000
WALLS	25	CY	300.00	7,500
8" CONCRETE BLOCK WALLS	640	SF	7.50	4,800
ROOF	240	SF	10.00	2,400
DOOR - 3'x7'	1	EA	750.00	750
HVAC	240	SF	5.00	1,200
LP HEATER	1	LS	1000.00	1,000
ELECTRICAL LIGHTS & POWER	240	SF	7.50	1,800
POWER PANEL	1	EA	2500.00	2,500
TRANSFORMER, 30 KVA	1	EA	2200.00	2,200
PIPE, VALVES & FITTINGS	1	LS	25000.00	25,000
4" FLOW METER	6	EA	2500.00	15,000
2" AIR RELEASE VALVE	6	EA	250.00	1,500
LAND EASEMENTS	3	AC	1200.00	3,600
TOTAL FOR 1				74,250
TOTAL FOR 2				$148,500
UNDEVELOPED DESIGN DETAILS ~20%				643,800
TOTAL GROUNDWATER EXTRACTION PUMPS & PIPING				$3,863,000

DATE:04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SOPA-GW2 AIR STRIPPING -
GROUNDWATER EXTRACTION SCENARIO 2
LOCATION: SOUTHERN OFF-POST AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SOPA-GW2 A/S + GWE 2 TREATMENT PLANT BUILDING DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
PUMP PIT & EQUALIZATION BASINS				
EXCAVATION	3400	CY	2.00	$6,800
BACKFILL	2000	CY	3.50	7,000
SPOIL	1400	CY	2.00	2,800
CONCRETE				
SLAB	150	CY	150.00	22,500
WALLS	265	CY	250.00	66,250
ELEVATED SLAB	25	CY	350.00	8,750
HANDRAIL	48	LF	20.00	960
LADDER	16	VLF	50.00	800
FLOOR HATCH - 6x8	6	EA	3000.00	18,000
3x3	1	EA	800.00	800
LIGHTS & MISC POWER	700	SF	7.50	5,250
HVAC	700	SF	5.00	3,500
PROCESS AREA				
PRE-ENGINEERED BUILDING, 16' EAVE 22' RIDGE HT, 74'W x 100'L	7400	SF	22.00	162,800
DOORS - 3'x7'	5	EA	750.00	3,750
6'x7'	2	EA	1050.00	2,100
ROLLING 12'x12'	2	EA	2750.00	5,500
WINDOWS - 4'x4'	5	EA	850.00	4,250
FLOOR TRENCH CONCRETE	55	CY	250.00	13,750
GRATING	1100	SF	25.00	27,500
INTERIOR PARTITION	2200	SF	7.00	15,400
LIGHTS & MISC POWER	7400	SF	6.00	44,400
HVAC	7400	SF	5.00	37,000
PAINTING	4400	SF	1.00	4,400
PAVING	650	SY	12.50	8,125
		TOTAL THIS SHEET		$472,385

DATE:04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION SOPA-GW2 AIR STRIPPING -
GROUNDWATER EXTRACTION SCENARIO 2
JOB # 6853-09

LOCATION: SOUTHERN OFF-POST AREA
BADGER ARMY AMMUNITION PLANT

ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SOPA-GW2 A/S + GWE 2 TREATMENT PLANT BUILDING DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
TOTAL PAGE 4				$472,385
OFFICE AREA				
SLAB FLOOR, 8' MIN CLG, SHED TYPE	1500	SF	20.00	30,000
INTERIOR PARTITIONS	544	SF	7.00	3,808
FINISHES				
OFFICE	780	SF	4.50	3,510
CLOSET	64	SF	8.00	512
TOILET	144	SF	20.00	2,880
ELECTRICAL ROOM	480	SF	3.50	1,680
ELECTRICAL WORK				
OFFICE	780	SF	10.00	7,800
CLOSET	64	SF	6.00	384
TOILET	144	SF	7.50	1,080
ELECTRICAL ROOM	480	SF	6.00	2,880
HVAC				
OFFICE	780	SF	7.50	5,850
CLOSET	64	SF	5.00	320
TOILET	144	SF	7.50	1,080
ELECTRICAL ROOM	480	SF	5.00	2,400
DOORS - 3'x7'	2	EA	750.00	1,500
WINDOWS - 4'x4'	6	EA	850.00	5,100
LAND	0.75	AC	1200.00	900
POTABLE WATER SUPPLY	1	LS	10000.00	10,000
SEPTIC SYSTEM	1	LS	5000.00	5,000
UNDEVELOPED DESIGN DETAILS ~20%				111,931
TOTAL TREATMENT PLANT BUILDING				$671,000

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION SOPA-GW2 AIR STRIPPING -
GROUNDWATER EXTRACTION SCENARIO 2

JOB # 6853-09

LOCATION: SOUTHERN OFF-POST AREA
BADGER ARMY AMMUNITION PLANT

ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SOPA-GW2 A/S + GWE 2 TREATMENT PLANT PROCESS EQUIPMENT DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
SELF CLEANING STRAINER	2	EA	20000.00	$40,000
INFLUENT PUMPS, 3000 GPM, 60 HP	3	EA	15000.00	45,000
AIR STRIPPING TOWER, BLOWER & DUCTWORK	2	LS	240000.00	480,000
OFF GAS HEATER & DUCTWORK	2	EA	10000.00	20,000
VAPOR PHASE CARBON UNITS	6	EA	45000.00	270,000
VENT STACK	2	LS	25000.00	50,000
18" DIA PVC PIPE, VALVES, FITTINGS	300	LF	300.00	90,000
AIR COMPRESSOR	1	LS	10000.00	10,000
AIR PIPE, FITTINGS, VALVES	500	LF	25.00	12,500
WATER PIPE, FITTINGS, VALVES	500	LF	25.00	12,500

UNDEVELOPED DESIGN DETAILS ~20%	206,000
TOTAL TREATMENT PLANT PROCESS EQUIPMENT	$1,236,000

DATE:04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SOPA-GW2 AIR STRIPPING -
GROUNDWATER EXTRACTION SCENARIO 2
LOCATION: SOUTHERN OFF-POST AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SOPA-GW2 A/S + GWE 2 ELECTRICAL & INSTRUMENTATION DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
GROUNDWATER EXTRACTION				
UNDERGROUND DUCT, 4x3 CND, 14"x18"	5600	LF	100.00	560,000
POWER CABLE TO PUMPS, 4-2/0	20000	LF	10.00	200,000
4-1/0	15000	LF	8.00	120,000
POWER CABLE TO METERING STATION				
4-1/0	3500	LF	8.00	28,000
INSTRUMENTATION CABLE				
TO WELL LEVEL SENSOR	35000	LF	1.00	35,000
TO METER STATION FLOW METERS	21000	LF	1.00	21,000
PROCESS EQUIPMENT				
ELECTRICAL UTILITY SERVICE	1	LS	80000.00	80,000
MOTOR CONTROL CENTER	1	LS	75000.00	75,000
300 KVA XFMR	1	EA	8800.00	8,800
225A, 277/480V 42 CKT PANEL BOARD	1	EA	3500.00	3,500
225A, 120/208V 42 CKT PANEL BOARD	1	EA	1925.00	1,925
LARGE POWER CIRCUITS				
4-#3, 1.25" C	300	LF	13.25	3,975
4-#4, 1.25" C	450	LF	12.65	5,693
6-500MCM, 4" C PER PHASE	200	LF	215.00	43,000
4-#2, 1.25" C	500	LF	14.00	7,000
4-#12, 3/4" C	1500	LF	7.50	11,250
INSTRUMENTATION				
CONTROL PANEL	1	LS	75000.00	75,000
PROCESS AREA INSTRUMENTATION	15	EA	2500.00	37,500
WIRING	4000	LF	6.50	26,000
UNDEVELOPED DESIGN DETAILS ~20%				268,358
TOTAL ELECTRICAL & INSTRUMENTATION				$1,611,000

DATE:04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SOPA-GW2 AIR STRIPPING -
GROUNDWATER EXTRACTION SCENARIO 2
LOCATION: SOUTHERN OFF-POST AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SOPA-GW2 A/S + GWE 2 GRAVITY DISCHARAGE DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
36" DIA RCP	4000	LF	130.00	$520,000
MANHOLE	5	EA	3000.00	15,000
DISCHARGE HEADWALL	1	LS	20000.00	20,000
LAND EASEMENT	3	AC	1200.00	3,600
UNDEVELOPED DESIGN DETAILS ~20%				111,400
TOTAL GRAVITY DISCHARGE				$670,000
EDUCATION PLAN PREPARATION	1	LS	50000.00	$50,000

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION SOPA-GW2 AIR STRIPPING -
GROUNDWATER EXTRACTION SCENARIO 2
JOB # 6853-09

LOCATION: SOUTHERN OFF-POST AREA
BADGER ARMY AMMUNITION PLANT

ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SOPA-GW2 A/S + GWE 2
ANNUAL OPERATION & MAINTENANCE

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
PUMPING & BLOWER ELECTRICAL	5225000	KWHR	0.04	$209,000
BUILDING ELECTRICAL	1300000	KWHR	0.04	52,000
OFF GAS HEATING (400 GAL PROPANE/DAY)	146000	GAL	0.50	73,000
GROUNDWATER MONITORING	1	LS	160540.00	160,540
EDUCATIONAL PROGRAMS	1	LS	5000.00	5,000
INFLUENT SAMPLING - VOLATILES	120	SMPL	275.00	33,000
INORGANICS	120	SMPL	163.00	19,560
EFFLUENT SAMPLING - VOLATILES	24	SMPL	275.00	6,600
INORGANICS	24	SMPL	163.00	3,912
AIR SAMPLING - VOLATILES	4	EA	150.00	600
PARTICULATES	4	EA	50.00	200
LABOR COSTS - 2 MEN/YEAR	4160	HR	30.00	124,800
MAINTENANCE COSTS	5.00%	LS	6710000.00	335,500
CARBON REPLACEMENT EACH 10 YEARS ($18,000 PER UNIT FOR 6 UNITS)	0.079504	LS	108000.00	8,586
FIVE YEAR SITE REVIEW @ $10,000 EVERY FIVE YEARS	0.180974	LS	10000.00	1,810
CONTINGENCY ~10%				103,892
TOTAL ANNUAL OPERATING & MAINTENANCE COSTS				$1,138,000

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SOPA-GW2 AIR STRIPPING -
GROUNDWATER EXTRACTION SCENARIO 3
LOCATION: SOUTHERN OFF-POST AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SOPA-GW2 A/S + GWE 3
COST SUMMARY TABLE

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
DIRECT COST OF OPTION SOPA-GW2 A/S + GWE 3				
SITE PREPARATION AND MOB/DEMOB				$578,000
GROUNDWATER EXTRACTION PUMPS & PIPING				8,150,000
TREATMENT PLANT BUILDING				999,000
TREATMENT PLANT PROCESS EQUIPMENT				2,382,000
ELECTRICAL & INSTRUMENTATION				3,419,000
GRAVITY DISCHARGE				856,000
EDUCATION PLAN PREPARATION				50,000
TOTAL DIRECT COST OF OPTION SOPA-GW2 A/S + GWE 3				$16,434,000
INDIRECT COST OF OPTION SOPA-GW2 A/S + GWE 3				
HEALTH AND SAFETY			5.00%	$822,000
LEGAL, ADMIN, PERMITTING			5.00%	822,000
ENGINEERING			10.00%	1,643,000
SERVICES DURING CONSTRUCTION			10.00%	1,643,000
TOTAL INDIRECT COST OF OPTION SOPA-GW2 A/S + GWE 3				$4,930,000
TOTAL CAPITAL (DIRECT + INDIRECT) COST				$21,364,000
OPERATING AND MAINTENANCE COSTS				
TOTAL ANNUAL OPERATING AND MAINTENANCE COSTS				$1,905,000
TOTAL PRESENT WORTH OF ANNUAL O&M COSTS (5% FOR SEVENTEEN YEARS)				$21,477,000
TOTAL PRESENT WORTH OF OPERATING AND MAINTENANCE COSTS				$21,477,000
TOTAL COST OF OPTION SOPA-GW2 A/S + GWE 3				$42,841,000

DATE:04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION SOPA-GW2 AIR STRIPPING -
GROUNDWATER EXTRACTION SCENARIO 3 JOB # 6853-09
LOCATION: SOUTHERN OFF-POST AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SOPA-GW2 A/S + GWE 3
SITE PREPARATION AND MOB/DEMOB

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
EQUIPMENT (IN OR OUT)				
FRONT END LOADER	4	EA	520.00	$2,080
DUMP TRUCKS	8	EA	260.00	2,080
BACKHOE	4	EA	950.00	3,800
WELL DRILLER	2	LS	10000.00	20,000
OFFICE TRAILER	12	MON	155.00	1,860
STORAGE TRAILER (2 EA)	24	MON	155.00	3,720
TRAILER SET-UP & DELIVERY, REMOVAL	3	EA	310.00	930
TOILET (2 EA*12 MON/EA)	104	WK	25.00	2,600
WATER CLR (2EA*12MON/EA)	104	WK	25.00	2,600
WATER (104 WK * 5 DAY/WK)	520	DAY	15.00	7,800
TELEPHONE SERVICE	12	MON	520.00	6,240
ELECTRICAL HOOK-UP	1	LS	2500.00	2,500
ELECTRICAL POWER	12	MON	300.00	3,600
PICK-UP (2 EA * 12 MON/EA)	24	MON	1035.00	24,840
OFFICE EQUIPMENT	12	MON	1035.00	12,420
PUMPS, TOOLS MINOR EQUIPMENT	1	LS	5000.00	5,000
VEHICLE PARKING AREA				
CLEAR & GRUB LIGHT VEGETATION	0.5	AC	3825.00	1,913
GRADE	825	CY	2.00	1,650
GRAVEL - 12" THICK	2420	SY	3.50	8,470
DECON PAD	1	LS	10000.00	10,000
LABORER (2 MEN*10 DAY/MAN*8 HR/DAY)	160	MNHR	30.50	4,880
CARPENTER (2 MEN*10 DAY/MAN*8 HR/DAY)	160	MNHR	39.00	6,240
ELECTRICIAN (2 MEN*10 DAY/MAN*8 HR/DAY	160	MNHR	42.50	6,800
SITE SUPERINTENDANT (12 MON*210 HR/MON	2520	MNHR	62.25	156,870
FOREMAN (12 MON * 210 HR/MON)	2520	MNHR	51.75	130,410
CLERK/TYPIST (12 MON * 168 HR/MON)	2016	MNHR	26.00	52,416
UNDEVELOPED DESIGN DETAILS ~20%				96,282
TOTAL SITE PREPARATION AND MOB/DEMOB				$578,000

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SOPA-GW2 AIR STRIPPING -
GROUNDWATER EXTRACTION SCENARIO 3
LOCATION: SOUTHERN OFF-POST AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SOPA-GW2 A/S + GWE 3
GROUNDWATER EXTRACTION PUMPS & PIPING

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
EXTRACTION WELLS	24	EA	69600.00	$1,670,400
EXTRACTION PUMPS	24	EA	25000.00	600,000
EXTRACTION WELL PIPING				
8" HDPE WITH 12" CONTAINMENT	26300	LF	80.00	2,104,000
18" HDPE WITH 24" CONTAINMEN	8000	LF	265.00	2,120,000
METERING STATION (INCL LP GAS TANKS) - 4 REQ'D				
FOUNDATION - FTG & SLAB	25	CY	200.00	$5,000
WALLS	25	CY	300.00	7,500
8" CONCRETE BLOCK WALLS	640	SF	7.50	4,800
ROOF	240	SF	10.00	2,400
DOOR - 3'x7'	1	EA	750.00	750
HVAC	240	SF	5.00	1,200
LP HEATER	1	LS	1000.00	1,000
ELECTRICAL LIGHTS & POWER	240	SF	7.50	1,800
POWER PANEL	1	EA	2500.00	2,500
TRANSFORMER, 30 KVA	1	EA	2200.00	2,200
PIPE, VALVES & FITTINGS	1	LS	25000.00	25,000
4" FLOW METER	6	EA	2500.00	15,000
2" AIR RELEASE VALVE	6	EA	250.00	1,500
LAND EASEMENTS	3	AC	1200.00	3,600
TOTAL FOR 1				74,250
TOTAL FOR 4				$297,000
UNDEVELOPED DESIGN DETAILS ~20%				1,358,600
TOTAL GROUNDWATER EXTRACTION PUMPS & PIPING				$8,150,000

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SOPA-GW2 AIR STRIPPING -
GROUNDWATER EXTRACTION SCENARIO 3
LOCATION: SOUTHERN OFF-POST AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SOPA-GW2 A/S + GWE 3 TREATMENT PLANT BUILDING DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
PUMP PIT & EQUALIZATION BASINS				
EXCAVATION	5300	CY	2.00	$10,600
BACKFILL	2300	CY	3.50	8,050
SPOIL	3000	CY	2.00	6,000
CONCRETE				
SLAB	280	CY	150.00	42,000
WALLS	350	CY	250.00	87,500
ELEVATED SLAB	60	CY	350.00	21,000
HANDRAIL	100	LF	20.00	2,000
LADDER	16	VLF	50.00	800
FLOOR HATCH - 6x8	8	EA	3000.00	24,000
3x3	1	EA	800.00	800
LIGHTS & MISC POWER	1400	SF	7.50	10,500
HVAC	1400	SF	5.00	7,000
PROCESS AREA				
PRE-ENGINEERED BUILDING, 16' EAVE 28' RIDGE HT, 100'W x 100'L	10000	SF	21.50	215,000
DOORS - 3'x7'	7	EA	750.00	5,250
6'x7'	2	EA	1050.00	2,100
ROLLING 12'x12'	4	EA	2750.00	11,000
WINDOWS - 4'x4'	14	EA	850.00	11,900
FLOOR TRENCH CONCRETE	100	CY	250.00	25,000
GRATING	1520	SF	25.00	38,000
INTERIOR PARTITION	2400	SF	7.00	16,800
LIGHTS & MISC POWER	10000	SF	6.00	60,000
HVAC	10000	SF	5.00	50,000
PAINTING	4800	SF	1.00	4,800
PAVING	1400	SY	12.50	17,500
TOTAL THIS SHEET				$677,600

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SOPA-GW2 AIR STRIPPING -
GROUNDWATER EXTRACTION SCENARIO 3
LOCATION: SOUTHERN OFF-POST AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SOPA-GW2 A/S + GWE 3 TREATMENT PLANT BUILDING DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
TOTAL PAGE 4				$677,600
OFFICE AREA				
SLAB FLOOR, 8' MIN CLG, SHED TYPE	3000	SF	20.00	60,000
INTERIOR PARTITIONS	640	SF	7.00	4,480
FINISHES				
OFFICE	1200	SF	4.50	5,400
CLOSET	200	SF	8.00	1,600
TOILET	400	SF	20.00	8,000
ELECTRICAL ROOM	1200	SF	3.50	4,200
ELECTRICAL WORK				
OFFICE	1200	SF	10.00	12,000
CLOSET	200	SF	6.00	1,200
TOILET	400	SF	7.50	3,000
ELECTRICAL ROOM	1200	SF	6.00	7,200
HVAC				
OFFICE	1200	SF	7.50	9,000
CLOSET	200	SF	5.00	1,000
TOILET	400	SF	7.50	3,000
ELECTRICAL ROOM	1200	SF	5.00	6,000
DOORS - 3'x7'	3	EA	750.00	2,250
WINDOWS - 4'x4'	12	EA	850.00	10,200
LAND	1	AC	1200.00	1,200
POTABLE WATER SUPPLY	1	LS	10000.00	10,000
SEPTIC SYSTEM	1	LS	5000.00	5,000
UNDEVELOPED DESIGN DETAILS ~20%				166,670
TOTAL TREATMENT PLANT BUILDING				$999,000

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SOPA-GW2 AIR STRIPPING -
GROUNDWATER EXTRACTION SCENARIO 3
LOCATION: SOUTHERN OFF-POST AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SOPA-GW2 A/S + GWE 3
TREATMENT PLANT PROCESS EQUIPMENT

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
SELF CLEANING STRAINER	4	EA	20000.00	$80,000
INFLUENT PUMPS, 3000 GPM, 60 HP	5	EA	15000.00	75,000
AIR STRIPPING TOWER, BLOWER & DUCTWORK	4	LS	240000.00	960,000
OFF GAS HEATER & DUCTWORK	4	EA	10000.00	40,000
VAPOR PHASE CARBON UNITS	12	EA	45000.00	540,000
VENT STACK	4	LS	25000.00	100,000
18" DIA PVC PIPE, VALVES, FITTINGS	500	LF	300.00	150,000
AIR COMPRESSOR	1	LS	10000.00	10,000
AIR PIPE, FITTINGS, VALVES	600	LF	25.00	15,000
WATER PIPE, FITTINGS, VALVES	600	LF	25.00	15,000

UNDEVELOPED DESIGN DETAILS ~20%	397,000
TOTAL TREATMENT PLANT PROCESS EQUIPMENT	$2,382,000

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION SOPA-GW2 AIR STRIPPING -
GROUNDWATER EXTRACTION SCENARIO 3
JOB # 6853-09

LOCATION: SOUTHERN OFF-POST AREA
BADGER ARMY AMMUNITION PLANT

ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SOPA-GW2 A/S + GWE 3 ELECTRICAL & INSTRUMENTATION DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
GROUNDWATER EXTRACTION				
UNDERGROUND DUCT, 4x3 CND, 14"x18"	12300	LF	100.00	1,230,000
POWER CABLE TO PUMPS, 4-2/0	20000	LF	10.00	200,000
4-1/0	30000	LF	8.00	240,000
4-4/0	30000	LF	14.00	420,000
POWER CABLE TO METERING STATION				
4-1/0	8000	LF	8.00	64,000
INSTRUMENTATION CABLE				
TO WELL LEVEL SENSOR	70000	LF	1.00	70,000
TO METER STATION FLOW METERS	48000	LF	1.00	48,000
PROCESS EQUIPMENT				
ELECTRICAL UTILITY SERVICE	1	LS	100000.00	100,000
MOTOR CONTROL CENTER	1	LS	120000.00	120,000
500 KVA XFMR	1	EA	13500.00	13,500
225A, 277/480V 42 CKT PANEL BOARD	2	EA	3500.00	7,000
225A, 120/208V 42 CKT PANEL BOARD	2	EA	1925.00	3,850
LARGE POWER CIRCUITS				
4-#3, 1.25" C	600	LF	13.25	7,950
4-#4, 1.25" C	1250	LF	12.65	15,813
6-500MCM, 4" C PER PHASE	400	LF	215.00	86,000
4-#2, 1.25" C	1600	LF	14.00	22,400
4-#12, 3/4" C	2400	LF	7.50	18,000
INSTRUMENTATION				
CONTROL PANEL	1	LS	100000.00	100,000
PROCESS AREA INSTRUMENTATION	20	EA	2500.00	50,000
WIRING	5000	LF	6.50	32,500
UNDEVELOPED DESIGN DETAILS ~20%				569,988
TOTAL ELECTRICAL & INSTRUMENTATION				$3,419,000

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION SOPA-GW2 AIR STRIPPING -
GROUNDWATER EXTRACTION SCENARIO 3
JOB # 6853-09

LOCATION: SOUTHERN OFF-POST AREA
BADGER ARMY AMMUNITION PLANT

ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SOPA-GW2 A/S + GWE 3 GRAVITY DISCHARGE DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
48" DIA RCP	4000	LF	165.00	$660,000
MANHOLE	5	EA	4000.00	20,000
DISCHARGE HEADWALL	1	LS	30000.00	30,000
LAND EASEMENT	3	AC	1200.00	3,600
UNDEVELOPED DESIGN DETAILS ~20%				142,400
TOTAL GRAVITY DISCHARGE				$856,000
EDUCATION PLAN PREPARATION	1	LS	50000.00	$50,000

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION SOPA-GW2 AIR STRIPPING -
GROUNDWATER EXTRACTION SCENARIO 3
JOB # 6853-09
LOCATION: SOUTHERN OFF-POST AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SOPA-GW2 A/S + GWE 3 ANNUAL OPERATION & MAINTENANCE DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
PUMPING & BLOWER ELECTRICAL	10200000	KWHR	0.04	$408,000
BUILDING ELECTRICAL	2600000	KWHR	0.04	104,000
OFF GAS HEATING (800 GAL PROPANE/DAY)	292000	GAL	0.50	146,000
GROUNDWATER MONITORING	1	LS	160540.00	160,540
EDUCATIONAL PROGRAMS	1	LS	5000.00	5,000
INFLUENT SAMPLING - VOLATILES	216	SMPL	275.00	59,400
INORGANICS	216	SMPL	163.00	35,208
EFFLUENT SAMPLING - VOLATILES	24	SMPL	275.00	6,600
INORGANICS	24	SMPL	163.00	3,912
AIR SAMPLING - VOLATILES	4	EA	150.00	600
PARTICULATES	4	EA	50.00	200
LABOR COSTS - 2 MEN/YEAR	4160	HR	30.00	124,800
MAINTENANCE COSTS	5.00%	LS	13170000.00	658,500
CARBON REPLACEMENT EACH 10 YEARS ($18,000 PER UNIT FOR 12 UNITS)	0.079504	LS	216000.00	17,173
FIVE YEAR SITE REVIEW @ $10,000 EVERY FIVE YEARS	0.180974	LS	10000.00	1,810
CONTINGENCY ~10%				173,257
TOTAL ANNUAL OPERATING & MAINTENANCE COSTS				$1,905,000

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SOPA-GW3 CARBON ADSORPTION -
GROUNDWATER EXTRACTION SCENARIO 1
LOCATION: SOUTHERN OFF-POST AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SOPA-GW3 CA + GWE 1
COST SUMMARY TABLE

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
DIRECT COST OF OPTION SOPA-GW3 CA + GWE 1				
SITE PREPARATION AND MOB/DEMOB				$399,000
GROUNDWATER EXTRACTION PUMPS & PIPING				2,042,000
TREATMENT PLANT BUILDING				412,000
TREATMENT PLANT PROCESS EQUIPMENT				726,000
ELECTRICAL & INSTRUMENTATION				1,008,000
GRAVITY DISCHARGE				346,000
EDUCATION PLAN PREPARATION				50,000
TOTAL DIRECT COST OF OPTION SOPA-GW3 CA + GWE 1				$4,983,000
INDIRECT COST OF OPTION SOPA-GW3 CA + GWE 1				
HEALTH AND SAFETY			5.00%	$249,000
LEGAL, ADMIN, PERMITTING			5.00%	249,000
ENGINEERING			10.00%	498,000
SERVICES DURING CONSTRUCTION			10.00%	498,000
TOTAL INDIRECT COST OF OPTION SOPA-GW3 CA + GWE 1				$1,494,000
TOTAL CAPITAL (DIRECT + INDIRECT) COST				$6,477,000
OPERATING AND MAINTENANCE COSTS				
TOTAL ANNUAL OPERATING AND MAINTENANCE COSTS				$822,000
TOTAL PRESENT WORTH OF ANNUAL O&M COSTS (5% FOR SIXTY-ONE YEARS)				$15,602,000
TOTAL PRESENT WORTH OF OPERATING AND MAINTENANCE COSTS				$15,602,000
TOTAL COST OF OPTION SOPA-GW3 CA + GWE 1				$22,079,000

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION SOPA-GW3 CARBON ADSORPTION - GROUNDWATER EXTRACTION SCENARIO 1
JOB # 6853-09
LOCATION: SOUTHERN OFF-POST AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SOPA-GW3 CA + GWE 1
SITE PREPARATION AND MOB/DEMOB

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
EQUIPMENT (IN OR OUT)				
FRONT END LOADER	2	EA	520.00	$1,040
DUMP TRUCKS	4	EA	260.00	1,040
BACKHOE	2	EA	950.00	1,900
WELL DRILLER	1	LS	10000.00	10,000
OFFICE TRAILER	8	MON	155.00	1,240
STORAGE TRAILER (2 EA)	16	MON	155.00	2,480
TRAILER SET-UP & DELIVERY, REMOVAL	3	EA	310.00	930
TOILET (2 EA*8 MON/EA)	70	WK	25.00	1,750
WATER CLR (2EA*8MON/EA)	70	WK	25.00	1,750
WATER (70 WK * 5 DAY/WK)	350	DAY	15.00	5,250
TELEPHONE SERVICE	8	MON	520.00	4,160
ELECTRICAL HOOK-UP	1	LS	2500.00	2,500
ELECTRICAL POWER	8	MON	300.00	2,400
PICK-UP (2 EA * 8 MON/EA)	16	MON	1035.00	16,560
OFFICE EQUIPMENT	8	MON	1035.00	8,280
PUMPS, TOOLS MINOR EQUIPMENT	1	LS	5000.00	5,000
VEHICLE PARKING AREA				
CLEAR & GRUB LIGHT VEGETATION	0.5	AC	3825.00	1,913
GRADE	825	CY	2.00	1,650
GRAVEL - 12" THICK	2420	SY	3.50	8,470
DECON PAD	1	LS	10000.00	10,000
LABORER (2 MEN*10 DAY/MAN*8 HR/DAY)	160	MNHR	30.50	4,880
CARPENTER (2 MEN*10 DAY/MAN*8 HR/DAY)	160	MNHR	39.00	6,240
ELECTRICIAN (2 MEN*10 DAY/MAN*8 HR/DAY	160	MNHR	42.50	6,800
SITE SUPERINTENDANT (8 MON*210 HR/MON)	1680	MNHR	62.25	104,580
FOREMAN (8 MON * 210 HR/MON)	1680	MNHR	51.75	86,940
CLERK/TYPIST (8 MON * 168 HR/MON)	1344	MNHR	26.00	34,944
UNDEVELOPED DESIGN DETAILS ~20%				66,304
TOTAL SITE PREPARATION AND MOB/DEMOB				$399,000

DATE:04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SOPA-GW3 CARBON ADSORPTION -
GROUNDWATER EXTRACTION SCENARIO 1
LOCATION: SOUTHERN OFF-POST AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SOPA-GW3 CA + GWE 1
GROUNDWATER EXTRACTION PUMPS & PIPING

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
EXTRACTION WELLS	6	EA	69600.00	$417,600
EXTRACTION PUMPS	6	EA	25000.00	150,000
EXTRACTION WELL PIPING				
8" HDPE WITH 12" CONTAINMENT	5300	LF	80.00	424,000
18" HDPE WITH 24" CONTAINMEN	2400	LF	265.00	636,000
METERING STATION (INCL LP GAS TANKS)				
FOUNDATION - FTG & SLAB	25	CY	200.00	5,000
WALLS	25	CY	300.00	7,500
8" CONCRETE BLOCK WALLS	640	SF	7.50	4,800
ROOF	240	SF	10.00	2,400
DOOR - 3'x7'	1	EA	750.00	750
HVAC	240	SF	5.00	1,200
LP HEATER	1	LS	1000.00	1,000
ELECTRICAL LIGHTS & POWER	240	SF	7.50	1,800
POWER PANEL	1	EA	2500.00	2,500
TRANSFORMER, 30 KVA	1	EA	2200.00	2,200
PIPE, VALVES & FITTINGS	1	LS	25000.00	25,000
4" FLOW METER	6	EA	2500.00	15,000
2" AIR RELEASE VALVE	6	EA	250.00	1,500
LAND EASEMENTS	3	AC	1200.00	3,600
UNDEVELOPED DESIGN DETAILS ~20%				340,150
TOTAL GROUNDWATER EXTRACTION PUMPS & PIPING				$2,042,000

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SOPA-GW3 CARBON ADSORPTION -
GROUNDWATER EXTRACTION SCENARIO 1
LOCATION: SOUTHERN OFF-POST AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SOPA-GW3 CA + GWE 1 TREATMENT PLANT BUILDING DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
PUMP PIT & EQUALIZATION BASINS				
EXCAVATION	2500	CY	2.00	$5,000
BACKFILL	1500	CY	3.50	5,250
SPOIL	1000	CY	2.00	2,000
CONCRETE				
SLAB	100	CY	150.00	15,000
WALLS	200	CY	250.00	50,000
ELEVATED SLAB	20	CY	350.00	7,000
HANDRAIL	64	LF	20.00	1,280
LADDER	16	VLF	50.00	800
FLOOR HATCH - 6x8	4	EA	3000.00	12,000
3x3	1	EA	800.00	800
LIGHTS & MISC POWER	400	SF	7.50	3,000
HVAC	400	SF	5.00	2,000
PROCESS AREA				
PRE-ENGINEERED BUILDING, 30' EAVE 34' RIDGE HT, 36'W x 50'L	1800	SF	32.50	58,500
DOORS - 3'x7'	2	EA	750.00	1,500
6'x7'	2	EA	1050.00	2,100
ROLLING 12'x12'	2	EA	2750.00	5,500
WINDOWS - 4'x4'	2	EA	850.00	1,700
FLOOR TRENCH CONCRETE	30	CY	250.00	7,500
GRATING	456	SF	25.00	11,400
LIGHTS & MISC POWER	1800	SF	8.50	15,300
HVAC	1800	SF	6.50	11,700
SHED TYPE BUILDING, 16' EAVE HT	1768	SF	22.50	39,780
DOORS - 3'x7'	1	EA	750.00	750
WINDOWS - 4'x4'	1	EA	850.00	850
LIGHTS & MISC POWER	7	SF	7.00	49
HVAC	6	SF	6.00	36
TOTAL THIS SHEET				$260,795

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SOPA-GW3 CARBON ADSORPTION -
GROUNDWATER EXTRACTION SCENARIO 1
LOCATION: SOUTHERN OFF-POST AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SOPA-GW3 CA + GWE 1 TREATMENT PLANT BUILDING DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
TOTAL PAGE 4				$260,795
OFFICE AREA				
SLAB FLOOR, 8' MIN CLG, SHED TYPE	1456	SF	20.00	29,120
INTERIOR PARTITIONS	496	SF	7.00	3,472
FINISHES				
OFFICE	504	SF	4.50	2,268
CLOSET	36	SF	8.00	288
TOILET	108	SF	20.00	2,160
ELECTRICAL ROOM	560	SF	3.50	1,960
ELECTRICAL WORK				
OFFICE	504	SF	10.00	5,040
CLOSET	36	SF	6.00	216
TOILET	108	SF	7.50	810
ELECTRICAL ROOM	560	SF	6.00	3,360
HVAC				
OFFICE	504	SF	7.50	3,780
CLOSET	36	SF	5.00	180
TOILET	108	SF	7.50	810
ELECTRICAL ROOM	560	SF	5.00	2,800
DOORS - 3'x7'	2	EA	750.00	1,500
WINDOWS - 4'x4'	4	EA	850.00	3,400
LAND	0.5	AC	1200.00	600
POTABLE WATER SUPPLY	1	LS	10000.00	10,000
SEPTIC SYSTEM	1	LS	5000.00	5,000
PAVING	450	SY	12.50	5,625
UNDEVELOPED DESIGN DETAILS ~20%				68,816
TOTAL TREATMENT PLANT BUILDING				$412,000

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SOPA-GW3 CARBON ADSORPTION -
GROUNDWATER EXTRACTION SCENARIO 1
LOCATION: SOUTHERN OFF-POST AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SOPA-GW3 CA + GWE 1

TREATMENT PLANT PROCESS EQUIPMENT DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
SELF CLEANING STRAINER	1	EA	20000.00	$20,000
INFLUENT PUMPS, 3000 GPM, 160 HP	2	EA	25000.00	50,000
LIQUID PHASE CARBON UNITS	6	EA	80000.00	480,000
18" DIA PVC PIPE, VALVES, FITTINGS	100	LF	300.00	30,000
AIR COMPRESSOR	1	LS	10000.00	10,000
AIR PIPE, FITTINGS, VALVES	300	LF	25.00	7,500
WATER PIPE, FITTINGS, VALVES	300	LF	25.00	7,500
UNDEVELOPED DESIGN DETAILS ~20%				121,000
TOTAL TREATMENT PLANT PROCESS EQUIPMENT				$726,000

DATE:04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SOPA-GW3 CARBON ADSORPTION -
GROUNDWATER EXTRACTION SCENARIO 1
LOCATION: SOUTHERN OFF-POST AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SOPA-GW3 CA + GWE 1 ELECTRICAL & INSTRUMENTATION DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
GROUNDWATER EXTRACTION				
UNDERGROUND DUCT, 4x3 CND, 14"x18"	3300	LF	100.00	330,000
POWER CABLE TO PUMPS, 4-2/0	20000	LF	10.00	200,000
POWER CABLE TO METERING STATION 4-1/0	2500	LF	8.00	20,000
INSTRUMENTATION CABLE				
TO WELL LEVEL SENSOR	20000	LF	1.00	20,000
TO METER STATION FLOW METERS	15000	LF	1.00	15,000
PROCESS EQUIPMENT				
ELECTRICAL UTILITY SERVICE	1	LS	75000.00	75,000
MOTOR CONTROL CENTER	1	LS	50000.00	50,000
150 KVA XFMR	1	EA	5250.00	5,250
225A, 277/480V 42 CKT PANEL BOARD	1	EA	3500.00	3,500
225A, 120/208V 42 CKT PANEL BOARD	1	EA	1925.00	1,925
LARGE POWER CIRCUITS				
4-2/0, 2" C	300	LF	22.00	6,600
6-500MCM, 4" C PER PHASE	100	LF	215.00	21,500
4-#2, 1.25" C	300	LF	14.00	4,200
4-#12, 3/4" C	800	LF	7.50	6,000
INSTRUMENTATION				
CONTROL PANEL	1	LS	40000.00	40,000
PROCESS AREA INSTRUMENTATION	10	EA	2500.00	25,000
WIRING	2500	LF	6.50	16,250
UNDEVELOPED DESIGN DETAILS ~20%				167,775
TOTAL ELECTRICAL & INSTRUMENTATION				$1,008,000

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION SOPA-GW3 CARBON ADSORPTION -
GROUNDWATER EXTRACTION SCENARIO 1

JOB # 6853-09

LOCATION: SOUTHERN OFF-POST AREA
BADGER ARMY AMMUNITION PLANT

ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SOPA-GW3 CA + GWE 1 GRAVITY DISCHARAGE DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
24" DIA RCP	4000	LF	65.00	$260,000
MANHOLE	5	EA	3000.00	15,000
DISCHARGE HEADWALL	1	LS	10000.00	10,000
LAND EASEMENT	3	AC	1200.00	3,600
UNDEVELOPED DESIGN DETAILS ~20%				57,400
TOTAL GRAVITY DISCHARGE				$346,000
EDUCATION PLAN PREPARATION	1	LS	50000.00	$50,000

DATE:04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SOPA-GW3 CARBON ADSORPTION -
GROUNDWATER EXTRACTION SCENARIO 1
LOCATION: SOUTHERN OFF-POST AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SOPA-GW3 CA + GWE 1 ANNUAL OPERATION & MAINTENANCE DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
PUMPING ELECTRICAL	2900000	KWHR	0.04	$116,000
BUILDING ELECTRICAL	750000	KWHR	0.04	30,000
GROUNDWATER MONITORING	1	LS	160540.00	160,540
EDUCATIONAL PROGRAMS	1	LS	5000.00	5,000
INFLUENT SAMPLING - VOLATILES	48	SMPL	275.00	13,200
INORGANICS	48	SMPL	163.00	7,824
EFFLUENT SAMPLING - VOLATILES	24	SMPL	275.00	6,600
INORGANICS	24	SMPL	163.00	3,912
LABOR COSTS - 1.5 MAN/YEAR	3120	HR	30.00	93,600
MAINTENANCE COSTS	5.00%	LS	3780000.00	189,000
CARBON REPLACEMENT (EACH LEAD UNIT TWICE PER YEAR)	6	UNIT	20000.00	120,000
FIVE YEAR SITE REVIEW @ $10,000 EVERY FIVE YEARS	0.180974	LS	10000.00	1,810
CONTINGENCY ~10%				74,514
TOTAL ANNUAL OPERATING & MAINTENANCE COSTS				$822,000

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SOPA-GW3 CARBON ADSORPTION -
GROUNDWATER EXTRACTION SCENARIO 2
LOCATION: SOUTHERN OFF-POST AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SOPA-GW3 CA + GWE 2
COST SUMMARY TABLE

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
DIRECT COST OF OPTION SOPA-GW3 CA + GWE 2				
SITE PREPARATION AND MOB/DEMOB				$480,000
GROUNDWATER EXTRACTION PUMPS & PIPING				3,863,000
TREATMENT PLANT BUILDING				724,000
TREATMENT PLANT PROCESS EQUIPMENT				1,458,000
ELECTRICAL & INSTRUMENTATION				1,602,000
GRAVITY DISCHARGE				670,000
EDUCATION PLAN PREPARATION				50,000
TOTAL DIRECT COST OF OPTION SOPA-GW3 CA + GWE 2				$8,847,000
INDIRECT COST OF OPTION SOPA-GW3 CA + GWE 2				
HEALTH AND SAFETY			5.00%	$442,000
LEGAL, ADMIN, PERMITTING			5.00%	442,000
ENGINEERING			10.00%	885,000
SERVICES DURING CONSTRUCTION			10.00%	885,000
TOTAL INDIRECT COST OF OPTION SOPA-GW3 CA + GWE 2				$2,654,000
TOTAL CAPITAL (DIRECT + INDIRECT) COST				$11,501,000
OPERATING AND MAINTENANCE COSTS				
TOTAL ANNUAL OPERATING AND MAINTENANCE COSTS				$1,335,000
TOTAL PRESENT WORTH OF ANNUAL O&M COSTS (5% FOR THIRTY-FOUR YEARS)				$21,618,000
TOTAL PRESENT WORTH OF OPERATING AND MAINTENANCE COSTS				$21,618,000
TOTAL COST OF OPTION SOPA-GW3 CA + GWE 2				$33,119,000

DATE:04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION SOPA-GW3 CARBON ADSORPTION -
GROUNDWATER EXTRACTION SCENARIO 2
JOB # 6853-09

LOCATION: SOUTHERN OFF-POST AREA
BADGER ARMY AMMUNITION PLANT

ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SOPA-GW3 CA + GWE 2 SITE PREPARATION AND MOB/DEMOB DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
EQUIPMENT (IN OR OUT)				
FRONT END LOADER	2	EA	520.00	$1,040
DUMP TRUCKS	4	EA	260.00	1,040
BACKHOE	2	EA	950.00	1,900
WELL DRILLER	1	LS	10000.00	10,000
OFFICE TRAILER	10	MON	155.00	1,550
STORAGE TRAILER (2 EA)	20	MON	155.00	3,100
TRAILER SET-UP & DELIVERY, REMOVAL	3	EA	310.00	930
TOILET (2 EA*10 MON/EA)	86	WK	25.00	2,150
WATER CLR (2EA*10MON/EA)	86	WK	25.00	2,150
WATER (86 WK * 5 DAY/WK)	430	DAY	15.00	6,450
TELEPHONE SERVICE	10	MON	520.00	5,200
ELECTRICAL HOOK-UP	1	LS	2500.00	2,500
ELECTRICAL POWER	10	MON	300.00	3,000
PICK-UP (2 EA * 10 MON/EA)	20	MON	1035.00	20,700
OFFICE EQUIPMENT	10	MON	1035.00	10,350
PUMPS, TOOLS MINOR EQUIPMENT	1	LS	5000.00	5,000
VEHICLE PARKING AREA				
CLEAR & GRUB LIGHT VEGETATION	0.5	AC	3825.00	1,913
GRADE	825	CY	2.00	1,650
GRAVEL - 12" THICK	2420	SY	3.50	8,470
DECON PAD	1	LS	10000.00	10,000
LABORER (2 MEN*10 DAY/MAN*8 HR/DAY)	160	MNHR	30.50	4,880
CARPENTER (2 MEN*10 DAY/MAN*8 HR/DAY)	160	MNHR	39.00	6,240
ELECTRICIAN (2 MEN*10 DAY/MAN*8 HR/DAY	160	MNHR	42.50	6,800
SITE SUPERINTENDANT (10 MON*210 HR/MON	2100	MNHR	62.25	130,725
FOREMAN (10 MON * 210 HR/MON)	2100	MNHR	51.75	108,675
CLERK/TYPIST (10 MON * 168 HR/MON)	1680	MNHR	26.00	43,680
UNDEVELOPED DESIGN DETAILS ~20%				79,908
TOTAL SITE PREPARATION AND MOB/DEMOB				$480,000

DATE:04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SOPA-GW3 CARBON ADSORPTION -
GROUNDWATER EXTRACTION SCENARIO 2
LOCATION: SOUTHERN OFF-POST AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SOPA-GW3 CA + GWE 2
GROUNDWATER EXTRACTION PUMPS & PIPING

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
EXTRACTION WELLS	12	EA	69600.00	$835,200
EXTRACTION PUMPS	12	EA	25000.00	300,000
EXTRACTION WELL PIPING				
8" HDPE WITH 12" CONTAINMENT	12600	LF	80.00	1,008,000
18" HDPE WITH 24" CONTAINMEN	3500	LF	265.00	927,500
METERING STATION (INCL LP GAS TANKS) - 2 REQ'D				
FOUNDATION - FTG & SLAB	25	CY	200.00	$5,000
WALLS	25	CY	300.00	7,500
8" CONCRETE BLOCK WALLS	640	SF	7.50	4,800
ROOF	240	SF	10.00	2,400
DOOR - 3'x7'	1	EA	750.00	750
HVAC	240	SF	5.00	1,200
LP HEATER	1	LS	1000.00	1,000
ELECTRICAL LIGHTS & POWER	240	SF	7.50	1,800
POWER PANEL	1	EA	2500.00	2,500
TRANSFORMER, 30 KVA	1	EA	2200.00	2,200
PIPE, VALVES & FITTINGS	1	LS	25000.00	25,000
4" FLOW METER	6	EA	2500.00	15,000
2" AIR RELEASE VALVE	6	EA	250.00	1,500
LAND EASEMENTS	3	AC	1200.00	3,600
TOTAL FOR 1				74,250
TOTAL FOR 2				$148,500
UNDEVELOPED DESIGN DETAILS ~20%				643,800
TOTAL GROUNDWATER EXTRACTION PUMPS & PIPING				$3,863,000

DATE:04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SOPA-GW3 CARBON ADSORPTION -
GROUNDWATER EXTRACTION SCENARIO 2
LOCATION: SOUTHERN OFF-POST AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SOPA-GW3 CA + GWE 2 TREATMENT PLANT BUILDING DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
PUMP PIT & EQUALIZATION BASINS				
EXCAVATION	3500	CY	2.00	$7,000
BACKFILL	1800	CY	3.50	6,300
SPOIL	1700	CY	2.00	3,400
CONCRETE				
SLAB	175	CY	150.00	26,250
WALLS	275	CY	250.00	68,750
ELEVATED SLAB	50	CY	350.00	17,500
HANDRAIL	80	LF	20.00	1,600
LADDER	16	VLF	50.00	800
FLOOR HATCH - 6x8	2	EA	4000.00	8,000
3x3	1	EA	800.00	800
LIGHTS & MISC POWER	1100	SF	7.50	8,250
HVAC	1100	SF	5.00	5,500
PROCESS AREA				
PRE-ENGINEERED BUILDING, 30' EAVE 36' RIDGE HT, 50'W x 72'L	3600	SF	32.00	115,200
DOORS - 3'x7'	4	EA	750.00	3,000
6'x7'	2	EA	1050.00	2,100
ROLLING 12'x12'	2	EA	2750.00	5,500
WINDOWS - 4'x4'	4	EA	850.00	3,400
FLOOR TRENCH CONCRETE	50	CY	250.00	12,500
GRATING	1000	SF	25.00	25,000
LIGHTS & MISC POWER	3600	SF	8.50	30,600
HVAC	3600	SF	6.50	23,400
SHED TYPE BLDG, 16' EAVE HT	2880	SF	22.50	64,800
DOORS - 3'x7'	1	EA	750.00	750
WINDOWS - 4'x4'	1	EA	850.00	850
LIGHTS & MISC POWER	2880	SF	7.00	20,160
HVAC	2880	SF	6.00	17,280

TOTAL THIS SHEET $478,690

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SOPA-GW3 CARBON ADSORPTION -
GROUNDWATER EXTRACTION SCENARIO 2
LOCATION: SOUTHERN OFF-POST AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SOPA-GW3 CA + GWE 2 TREATMENT PLANT BUILDING DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
TOTAL PAGE 4				$478,690
OFFICE AREA				
SLAB FLOOR, 8' MIN CLG, SHED TYPE	2160	SF	20.00	43,200
INTERIOR PARTITIONS	480	SF	7.00	3,360
FINISHES				
OFFICE	960	SF	4.50	4,320
CLOSET	100	SF	8.00	800
TOILET	200	SF	20.00	4,000
ELECTRICAL ROOM	900	SF	3.50	3,150
ELECTRICAL WORK				
OFFICE	960	SF	10.00	9,600
CLOSET	100	SF	6.00	600
TOILET	200	SF	7.50	1,500
ELECTRICAL ROOM	900	SF	6.00	5,400
HVAC				
OFFICE	960	SF	7.50	7,200
CLOSET	100	SF	5.00	500
TOILET	200	SF	7.50	1,500
ELECTRICAL ROOM	900	SF	5.00	4,500
DOORS - 3'x7'	3	EA	750.00	2,250
WINDOWS - 4'x4'	7	EA	850.00	5,950
LAND	0.75	AC	1200.00	900
POTABLE WATER SUPPLY	1	LS	10000.00	10,000
SEPTIC SYSTEM	1	LS	5000.00	5,000
PAVING	900	SY	12.50	11,250
UNDEVELOPED DESIGN DETAILS ~20%				120,330
TOTAL TREATMENT PLANT BUILDING				$724,000

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION SOPA-GW3 CARBON ADSORPTION -
GROUNDWATER EXTRACTION SCENARIO 2

JOB # 6853-09

LOCATION: SOUTHERN OFF-POST AREA
BADGER ARMY AMMUNITION PLANT

ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SOPA-GW3 CA + GWE 2
TREATMENT PLANT PROCESS EQUIPMENT

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
SELF CLEANING STRAINER	2	EA	20000.00	$40,000
INFLUENT PUMPS, 3000 GPM, 160 HP	3	EA	25000.00	75,000
LIQUID PHASE CARBON UNITS	12	EA	80000.00	960,000
18" DIA PVC PIPE, VALVES, FITTINGS	350	LF	300.00	105,000
AIR COMPRESSOR	1	LS	10000.00	10,000
AIR PIPE, FITTINGS, VALVES	500	LF	25.00	12,500
WATER PIPE, FITTINGS, VALVES	500	LF	25.00	12,500
UNDEVELOPED DESIGN DETAILS ~20%				243,000
TOTAL TREATMENT PLANT PROCESS EQUIPMENT				$1,458,000

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SOPA-GW3 CARBON ADSORPTION -
GROUNDWATER EXTRACTION SCENARIO 2
LOCATION: SOUTHERN OFF-POST AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SOPA-GW3 CA + GWE 2 ELECTRICAL & INSTRUMENTATION DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
GROUNDWATER EXTRACTION				
UNDERGROUND DUCT, 4x3 CND, 14"x18"	5600	LF	100.00	560,000
POWER CABLE TO PUMPS, 4-2/0	20000	LF	10.00	200,000
4-1/0	15000	LF	8.00	120,000
POWER CABLE TO METERING STATION				
4-1/0	3500	LF	8.00	28,000
INSTRUMENTATION CABLE				
TO WELL LEVEL SENSOR	35000	LF	1.00	35,000
TO METER STATION FLOW METERS	21000	LF	1.00	21,000
PROCESS EQUIPMENT				
ELECTRICAL UTILITY SERVICE	1	LS	80000.00	80,000
MOTOR CONTROL CENTER	1	LS	75000.00	75,000
300 KVA XFMR	1	EA	8800.00	8,800
225A, 277/480V 42 CKT PANEL BOARD	1	EA	3500.00	3,500
225A, 120/208V 42 CKT PANEL BOARD	1	EA	1925.00	1,925
LARGE POWER CIRCUITS				
4-2/0, 2" C	600	LF	22.00	13,200
6-500MCM, 4" C PER PHASE	200	LF	215.00	43,000
4-#2, 1.25" C	750	LF	14.00	10,500
4-#12, 3/4" C	1500	LF	7.50	11,250
INSTRUMENTATION				
CONTROL PANEL	1	LS	60000.00	60,000
PROCESS AREA INSTRUMENTATION	15	EA	2500.00	37,500
WIRING	4000	LF	6.50	26,000
UNDEVELOPED DESIGN DETAILS ~20%				267,325
TOTAL ELECTRICAL & INSTRUMENTATION				$1,602,000

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION SOPA-GW3 CARBON ADSORPTION -
GROUNDWATER EXTRACTION SCENARIO 2
JOB # 6853-09

LOCATION: SOUTHERN OFF-POST AREA
BADGER ARMY AMMUNITION PLANT

ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SOPA-GW3 CA + GWE 2 GRAVITY DISCHARAGE DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
36" DIA RCP	4000	LF	130.00	$520,000
MANHOLE	5	EA	3000.00	15,000
DISCHARGE HEADWALL	1	LS	20000.00	20,000
LAND EASEMENT	3	AC	1200.00	3,600
UNDEVELOPED DESIGN DETAILS ~20%				111,400
TOTAL GRAVITY DISCHARGE				$670,000
EDUCATION PLAN PREPARATION	1	LS	50000.00	$50,000

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SOPA-GW3 CARBON ADSORPTION -
GROUNDWATER EXTRACTION SCENARIO 2
LOCATION: SOUTHERN OFF-POST AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SOPA-GW3 CA + GWE 2 ANNUAL OPERATION & MAINTENANCE DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
PUMPING ELECTRICAL	5550000	KWHR	0.04	$222,000
BUILDING ELECTRICAL	1250000	KWHR	0.04	50,000
GROUNDWATER MONITORING	1	LS	160540.00	160,540
EDUCATIONAL PROGRAMS	1	LS	5000.00	5,000
INFLUENT SAMPLING - VOLATILES	120	SMPL	275.00	33,000
INORGANICS	120	SMPL	163.00	19,560
EFFLUENT SAMPLING - VOLATILES	24	SMPL	275.00	6,600
INORGANICS	24	SMPL	163.00	3,912
LABOR COSTS - 2 MEN/YEAR	4160	HR	30.00	124,800
MAINTENANCE COSTS	5.00%	LS	6930000.00	346,500
CARBON REPLACEMENT (EACH LEAD UNIT TWICE PER YEAR)	12	UNIT	20000.00	240,000
FIVE YEAR SITE REVIEW @ $10,000 EVERY FIVE YEARS	0.180974	LS	10000.00	1,810
CONTINGENCY ~10%				121,278
TOTAL ANNUAL OPERATING & MAINTENANCE COSTS				$1,335,000

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SOPA-GW3 CARBON ADSORPTION -
GROUNDWATER EXTRACTION SCENARIO 3
LOCATION: SOUTHERN OFF-POST AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SOPA-GW3 CA + GWE 3 COST SUMMARY TABLE DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
DIRECT COST OF OPTION SOPA-GW3 CA + GWE 3				
SITE PREPARATION AND MOB/DEMOB				$578,000
GROUNDWATER EXTRACTION PUMPS & PIPING				8,150,000
TREATMENT PLANT BUILDING				1,283,000
TREATMENT PLANT PROCESS EQUIPMENT				2,742,000
ELECTRICAL & INSTRUMENTATION				3,411,000
GRAVITY DISCHARGE				856,000
EDUCATION PLAN PREPARATION				50,000
TOTAL DIRECT COST OF OPTION SOPA-GW3 CA + GWE 3				$17,070,000
INDIRECT COST OF OPTION SOPA-GW3 CA + GWE 3				
HEALTH AND SAFETY			5.00%	$854,000
LEGAL, ADMIN, PERMITTING			5.00%	854,000
ENGINEERING			10.00%	1,707,000
SERVICES DURING CONSTRUCTION			10.00%	1,707,000
TOTAL INDIRECT COST OF OPTION SOPA-GW3 CA + GWE 3				$5,122,000
TOTAL CAPITAL (DIRECT + INDIRECT) COST				$22,192,000
OPERATING AND MAINTENANCE COSTS				
TOTAL ANNUAL OPERATING AND MAINTENANCE COSTS				$2,304,000
TOTAL PRESENT WORTH OF ANNUAL O&M COSTS (5% FOR SEVENTEEN YEARS)				$25,975,000
TOTAL PRESENT WORTH OF OPERATING AND MAINTENANCE COSTS				$25,975,000
TOTAL COST OF OPTION SOPA-GW3 CA + GWE 3				$48,167,000

DATE:04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SOPA-GW3 CARBON ADSORPTION -
GROUNDWATER EXTRACTION SCENARIO 3
LOCATION: SOUTHERN OFF-POST AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SOPA-GW3 CA + GWE 3 SITE PREPARATION AND MOB/DEMOB DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
EQUIPMENT (IN OR OUT)				
FRONT END LOADER	4	EA	520.00	$2,080
DUMP TRUCKS	8	EA	260.00	2,080
BACKHOE	4	EA	950.00	3,800
WELL DRILLER	2	LS	10000.00	20,000
OFFICE TRAILER	12	MON	155.00	1,860
STORAGE TRAILER (2 EA)	24	MON	155.00	3,720
TRAILER SET-UP & DELIVERY, REMOVAL	3	EA	310.00	930
TOILET (2 EA*12 MON/EA)	104	WK	25.00	2,600
WATER CLR (2EA*12MON/EA)	104	WK	25.00	2,600
WATER (104 WK * 5 DAY/WK)	520	DAY	15.00	7,800
TELEPHONE SERVICE	12	MON	520.00	6,240
ELECTRICAL HOOK-UP	1	LS	2500.00	2,500
ELECTRICAL POWER	12	MON	300.00	3,600
PICK-UP (2 EA * 12 MON/EA)	24	MON	1035.00	24,840
OFFICE EQUIPMENT	12	MON	1035.00	12,420
PUMPS, TOOLS MINOR EQUIPMENT	1	LS	5000.00	5,000
VEHICLE PARKING AREA				
CLEAR & GRUB LIGHT VEGETATION	0.5	AC	3825.00	1,913
GRADE	825	CY	2.00	1,650
GRAVEL - 12" THICK	2420	SY	3.50	8,470
DECON PAD	1	LS	10000.00	10,000
LABORER (2 MEN*10 DAY/MAN*8 HR/DAY)	160	MNHR	30.50	4,880
CARPENTER (2 MEN*10 DAY/MAN*8 HR/DAY)	160	MNHR	39.00	6,240
ELECTRICIAN (2 MEN*10 DAY/MAN*8 HR/DAY	160	MNHR	42.50	6,800
SITE SUPERINTENDANT (12 MON*210 HR/MON	2520	MNHR	62.25	156,870
FOREMAN (12 MON * 210 HR/MON)	2520	MNHR	51.75	130,410
CLERK/TYPIST (12 MON * 168 HR/MON)	2016	MNHR	26.00	52,416
UNDEVELOPED DESIGN DETAILS ~20%				96,282
TOTAL SITE PREPARATION AND MOB/DEMOB				$578,000

DATE:04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SOPA-GW3 CARBON ADSORPTION -
GROUNDWATER EXTRACTION SCENARIO 3
LOCATION: SOUTHERN OFF-POST AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SOPA-GW3 CA + GWE 3
GROUNDWATER EXTRACTION PUMPS & PIPING

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
EXTRACTION WELLS	24	EA	69600.00	$1,670,400
EXTRACTION PUMPS	24	EA	25000.00	600,000
EXTRACTION WELL PIPING				
8" HDPE WITH 12" CONTAINMENT	26300	LF	80.00	2,104,000
18" HDPE WITH 24" CONTAINMEN	8000	LF	265.00	2,120,000
METERING STATION (INCL LP GAS TANKS) - 4 REQ'D				
FOUNDATION - FTG & SLAB	25	CY	200.00	$5,000
WALLS	25	CY	300.00	7,500
8" CONCRETE BLOCK WALLS	640	SF	7.50	4,800
ROOF	240	SF	10.00	2,400
DOOR - 3'x7'	1	EA	750.00	750
HVAC	240	SF	5.00	1,200
LP HEATER	1	LS	1000.00	1,000
ELECTRICAL LIGHTS & POWER	240	SF	7.50	1,800
POWER PANEL	1	EA	2500.00	2,500
TRANSFORMER, 30 KVA	1	EA	2200.00	2,200
PIPE, VALVES & FITTINGS	1	LS	25000.00	25,000
4" FLOW METER	6	EA	2500.00	15,000
2" AIR RELEASE VALVE	6	EA	250.00	1,500
LAND EASEMENTS	3	AC	1200.00	3,600
TOTAL FOR 1				74,250
TOTAL FOR 4				$297,000

UNDEVELOPED DESIGN DETAILS ~20%	1,358,600
TOTAL GROUNDWATER EXTRACTION PUMPS & PIPING	$8,150,000

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION SOPA-GW3 CARBON ADSORPTION -
GROUNDWATER EXTRACTION SCENARIO 3
JOB # 6853-09

LOCATION: SOUTHERN OFF-POST AREA
BADGER ARMY AMMUNITION PLANT

ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SOPA-GW3 CA + GWE 3 TREATMENT PLANT BUILDING DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
PUMP PIT & EQUALIZATION BASINS				
EXCAVATION	5300	CY	2.00	$10,600
BACKFILL	2300	CY	3.50	8,050
SPOIL	3000	CY	2.00	6,000
CONCRETE				
SLAB	280	CY	150.00	42,000
WALLS	350	CY	250.00	87,500
ELEVATED SLAB	60	CY	350.00	21,000
HANDRAIL	100	LF	20.00	2,000
LADDER	16	VLF	50.00	800
FLOOR HATCH - 6x8	8	EA	3000.00	24,000
3x3	1	EA	800.00	800
LIGHTS & MISC POWER	1400	SF	7.50	10,500
HVAC	1400	SF	5.00	7,000
PROCESS AREA				
PRE-ENGINEERED BUILDING, 30' EAVE 38' RIDGE HT, 100'W x 86'L	8600	SF	31.50	270,900
DOORS - 3'x7'	6	EA	750.00	4,500
6'x7'	2	EA	1050.00	2,100
ROLLING 12'x12'	4	EA	2750.00	11,000
WINDOWS - 4'x4'	8	EA	850.00	6,800
FLOOR TRENCH CONCRETE	105	CY	250.00	26,250
GRATING	2060	SF	25.00	51,500
LIGHTS & MISC POWER	8600	SF	8.50	73,100
HVAC	8600	SF	6.50	55,900
SHED TYPE BLDG, 16' EAVE HT	5000	SF	21.50	107,500
DOORS - 3'x7'	1	EA	750.00	750
WINDOWS - 4'x4'	2	EA	850.00	1,700
LIGHTS & MISC POWER	5000	SF	7.00	35,000
HVAC	5000	SF	6.00	30,000

TOTAL THIS SHEET $897,250

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION SOPA-GW3 CARBON ADSORPTION -
GROUNDWATER EXTRACTION SCENARIO 3

JOB # 6853-09

LOCATION: SOUTHERN OFF-POST AREA
BADGER ARMY AMMUNITION PLANT

ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SOPA-GW3 CA + GWE 3 TREATMENT PLANT BUILDING DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
TOTAL PAGE 4				$897,250
OFFICE AREA				
SLAB FLOOR, 8' MIN CLG, SHED TYPE	3000	SF	20.00	60,000
INTERIOR PARTITIONS	640	SF	7.00	4,480
FINISHES				
OFFICE	1200	SF	4.50	5,400
CLOSET	200	SF	8.00	1,600
TOILET	400	SF	20.00	8,000
ELECTRICAL ROOM	1200	SF	3.50	4,200
ELECTRICAL WORK				
OFFICE	1200	SF	10.00	12,000
CLOSET	200	SF	6.00	1,200
TOILET	400	SF	7.50	3,000
ELECTRICAL ROOM	1200	SF	6.00	7,200
HVAC				
OFFICE	1200	SF	7.50	9,000
CLOSET	200	SF	5.00	1,000
TOILET	400	SF	7.50	3,000
ELECTRICAL ROOM	1200	SF	5.00	6,000
DOORS - 3'x7'	3	EA	750.00	2,250
WINDOWS - 4'x4'	12	EA	850.00	10,200
LAND	1	AC	1200.00	1,200
POTABLE WATER SUPPLY	1	LS	10000.00	10,000
SEPTIC SYSTEM	1	LS	5000.00	5,000
PAVING	1400	SY	12.50	17,500
UNDEVELOPED DESIGN DETAILS ~20%				213,520
TOTAL TREATMENT PLANT BUILDING				$1,283,000

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY
OPTION SOPA-GW3 CARBON ADSORPTION -
GROUNDWATER EXTRACTION SCENARIO 3 JOB # 6853-09

LOCATION: SOUTHERN OFF-POST AREA
BADGER ARMY AMMUNITION PLANT

ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SOPA-GW3 CA + GWE 3 TREATMENT PLANT PROCESS EQUIPMENT DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
SELF CLEANING STRAINER	4	EA	20000.00	$80,000
INFLUENT PUMPS, 3000 GPM, 160 HP	5	EA	25000.00	125,000
LIQUID PHASE CARBON UNITS	24	EA	80000.00	1,920,000
18" DIA PVC PIPE, VALVES, FITTINGS	400	LF	300.00	120,000
AIR COMPRESSOR	1	LS	10000.00	10,000
AIR PIPE, FITTINGS, VALVES	600	LF	25.00	15,000
WATER PIPE, FITTINGS, VALVES	600	LF	25.00	15,000
UNDEVELOPED DESIGN DETAILS ~20%				457,000
TOTAL TREATMENT PLANT PROCESS EQUIPMENT				$2,742,000

DATE:04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SOPA-GW3 CARBON ADSORPTION -
GROUNDWATER EXTRACTION SCENARIO 3
LOCATION: SOUTHERN OFF-POST AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SOPA-GW3 CA + GWE 3 ELECTRICAL & INSTRUMENTATION DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
GROUNDWATER EXTRACTION				
UNDERGROUND DUCT, 4x3 CND, 14"x18"	12300	LF	100.00	1,230,000
POWER CABLE TO PUMPS, 4-2/0	20000	LF	10.00	200,000
4-1/0	30000	LF	8.00	240,000
4-4/0	30000	LF	14.00	420,000
POWER CABLE TO METERING STATION				
4-1/0	8000	LF	8.00	64,000
INSTRUMENTATION CABLE				
TO WELL LEVEL SENSOR	70000	LF	1.00	70,000
TO METER STATION FLOW METERS	48000	LF	1.00	48,000
PROCESS EQUIPMENT				
ELECTRICAL UTILITY SERVICE	1	LS	100000.00	100,000
MOTOR CONTROL CENTER	1	LS	130000.00	130,000
500 KVA XFMR	1	EA	13500.00	13,500
225A, 277/480V 42 CKT PANEL BOARD	2	EA	3500.00	7,000
225A, 120/208V 42 CKT PANEL BOARD	2	EA	1925.00	3,850
LARGE POWER CIRCUITS				
4-2/0, 2" C	1250	LF	22.00	27,500
6-500MCM, 4" C PER PHASE	400	LF	215.00	86,000
4-#2, 1.25" C	1200	LF	14.00	16,800
4-#12, 3/4" C	1800	LF	7.50	13,500
INSTRUMENTATION				
CONTROL PANEL	1	LS	90000.00	90,000
PROCESS AREA INSTRUMENTATION	20	EA	2500.00	50,000
WIRING	5000	LF	6.50	32,500
UNDEVELOPED DESIGN DETAILS ~20%				568,350
TOTAL ELECTRICAL & INSTRUMENTATION				$3,411,000

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SOPA-GW3 CARBON ADSORPTION -
GROUNDWATER EXTRACTION SCENARIO 3
LOCATION: SOUTHERN OFF-POST AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SOPA-GW3 CA + GWE 3 GRAVITY DISCHARAGE DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
48" DIA RCP	4000	LF	165.00	$660,000
MANHOLE	5	EA	4000.00	20,000
DISCHARGE HEADWALL	1	LS	30000.00	30,000
LAND EASEMENT	3	AC	1200.00	3,600
UNDEVELOPED DESIGN DETAILS ~20%				142,400
TOTAL GRAVITY DISCHARGE				$856,000
EDUCATION PLAN PREPARATION	1	LS	50000.00	$50,000

DATE: 04-Aug-94 UNIT COST ESTIMATING WORKSHEET

PROJECT: FEASIBILITY STUDY JOB # 6853-09
OPTION SOPA-GW3 CARBON ADSORPTION -
GROUNDWATER EXTRACTION SCENARIO 3
LOCATION: SOUTHERN OFF-POST AREA
BADGER ARMY AMMUNITION PLANT
ENGINEER: ABB ENVIRONMENTAL SERVICES, INC.

ESTIMATOR: P. R. MARTIN

OPTION SOPA-GW3 CA + GWE 3 ANNUAL OPERATION & MAINTENANCE DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL
PUMPING ELECTRICAL	10850000	KWHR	0.04	$434,000
BUILDING ELECTRICAL	2450000	KWHR	0.04	98,000
GROUNDWATER MONITORING	1	LS	160540.00	160,540
EDUCATIONAL PROGRAMS	1	LS	5000.00	5,000
INFLUENT SAMPLING - VOLATILES	216	SMPL	275.00	59,400
INORGANICS	216	SMPL	163.00	35,208
EFFLUENT SAMPLING - VOLATILES	24	SMPL	275.00	6,600
INORGANICS	24	SMPL	163.00	3,912
LABOR COSTS - 2 MEN/YEAR	4160	HR	30.00	124,800
MAINTENANCE COSTS	5.00%	LS	13700000.00	685,000
CARBON REPLACEMENT (EACH LEAD UNIT TWICE EACH YEAR)	24	UNIT	20000.00	480,000
FIVE YEAR SITE REVIEW @ $10,000 EVERY FIVE YEARS	0.180974	LS	10000.00	1,810
CONTINGENCY ~10%				209,730
TOTAL ANNUAL OPERATING & MAINTENANCE COSTS				$2,304,000

APPENDIX H.3

VENDOR INFORMATION: GROUNDWATER ALTERNATIVES

SOUTHERN OFF-POST AREA

ABB
ASEA BROWN BOVERI

ABB Environmental Services, Inc.

261 Commercial Street/P.O. Box 7050 Portland, Maine 04112
(207) 775-5401 FAX (207) 773-0011

TELEPHONE MEMORANDUM

PROJECT NO.: 6853-09 DATE: 7/15/94

CLIENT: Badger

PROJECT DESCRIPTION: Final FS

BETWEEN: Chris Vaughan

AND: Rich Rushenburg Acting chief of apraisal Branch Omaha District

SUBJECT: Cost for Land concerning SDPA Treatment Facility

R.R. Suggested that Land would not be Purchased but easements would be the way to go.
He quoted: $1,200 /acre of affected land

- Assuming temporary construction easments of 30-50 ft for all piping down to 10-20 ft after Construction
- Compensation for any manholes needed @ $100 /manhole
- Inspection changes at $1000 /year
- All land is Dry crop land w/ some Irrigation

~~DISTRIBUTION:~~ Rich Rushenburg
ABB (402) 221-4347

1478-49 Form 4/6/90

ABB
ASEA BROWN BOVERI

ABB Environmental Services, Inc.
110 Free Street
P.O. Box 7050
Portland, Maine 04112-7050
Telephone (207) 775-5400
Fax (207) 772-4762

TELEPHONE MEMORANDUM

PROJECT NO.: 06853-09 DATE: 7/21/94
CLIENT: Badger
PROJECT DESCRIPTION: FS - SOTA
BETWEEN: Ken Gaynor - Hydro Group
AND: Chris Vaughan
SUBJECT: Extraction well Costs

For a Row of 6 extraction wells, each
well being ≈ -230 ft Deep
- 165 ft screen (10")
- 10" casing

→ would cost $417,600
which includes site prep + mobilization, well construction,
well Development

Extraction well Pump Grundfos 600S400-3 (40 HP)
would cost ≈ $25,000.

DISTRIBUTION:
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110 Free Street
P.O. Box 7050
Portland, Maine 04112-7050

Telephone (207) 775-5400

Fax (207) 772-4762

MEMORANDUM

PROJECT NO.: ______

DATE: 7/8/94

CLIENT: Army Environmental Center, Badger AAP

PROJECT DESCRIPTION: Groundwater Remediation

TO: Ken Marran Fax # (908) 563-1396

FROM: Chris Vaughan

SUBJECT: Evaluation of Airstripping and Carbon Adsorption (Aqueous)

Ken,

Per our phone conversation, I've attached a data sheet and a request for specific information. I'd like info. regarding both Air stripping and Aqueous Carbon Adsorption. The influent Concentrations were calculated using existing Monitoring data and the effluent Limits are what we would expect to see in a surface water discharge permit.

Carbon Tetrachloride is the limiting Compound as far as the air emissions from the stripper. The State standards allow a maximum of 25 lb/yr of CCl_4 into the atmosphere.

Please Call with any questions.

I'd like this info by 7/12/94 thanx,

if possible:

Chris

DISTRIBUTION:
ABB

Note: If you are unable to calculate Present value, I can calculate it using your annual O+M.

Cost Assumptions:

Labor Rate = $40/hr

Electricity = $0.04/KWHR

PROJECT	COMP. BY	JOB NO.
Air Stripping Evaluation & Carbon adsorption	CW	
	CHK. BY	DATE 7/8/94

Please Look @ all 3 Flow Scenario's Seperately:

1)

Scenario:	Scenario 1	Scenario 2	Scenario 3		
Average Flow:	3000 gpm (4.32 MGD)	6000 gpm (8.64 MGD)	12000 gpm (17.28 MGD)		
Compound	AVG. INF. CONC. (ug/l)	AVG. INF. CONC (ug/l)	AVG INF. CONC (ug/l)	EFFLUENT LIMIT (ug/l)	Source
CCl_4	10.0	7.5	6.0	< 1.0	WPDES Permit
$CHCl_3$	2.0	1.5	1.0	< 1.0	↓
TRCLE	1.0	1.0	1.0	< 1.0	↓

2) Concentrations of Parameters of interest in monitoring wells @ the site:

Parameter	Conc. Range (ug/l)
Background TOC	1,000 - 2000
Iron	27 - 75
Manganese	12 - 57
Alkalinity	200,000 - 600,000
Hardness	200,000 - 400,000
TDS	250,000 - 550,000

3) Temperature Range $10^{\circ} - 12^{\circ}C$

4) Cost Assumptions: Labor 40 /hr
Electricity 0.04 /KW HR

5) — Scaling Problem — Probably $CaCO_3$

MEMORANDUM (Cont.)

PROJECT NO.: 6853-09

DATE: 7/8/94

SHEET 3 OF 3

Information Request:

- Type and size of components
- Spatial Requirements of the System
- Required utilities
- Auxiliary Equipment
- Operation Parameters
- Secondary Wastestreams (Qnty & Disposal options)
- Manpower Requirements
- Simple Flow Diagram Including Auxiliary Equip.
- Capital Cost
- O & M cost
- Present value assuming a

Flow Scenario 1 – 73 years

Flow Scenario 2 – 23 years

Flow Scenario 3 – 11 years

If you have this type of info readily available I'd appreciate it

Thx
Chris

PROJECT	COMP. BY	JOB NO.
Badger FS Air stripper Design	[illegible]	
	CHK. BY	DATE 7/13/94

Discussed with Ken Marran 7/13/94

After Recieving design info. from Ken Marran (Hydro Group) I called him pertaining to treatment of the off-gas. He indicated that if offgas treatment was required the following changes should be made to his spec's written on 7/11/94:

1) Air to water Ratio 45:1
2) Air Flow Rate /tower 18,000 cfm
3) Increase Packed bed depth to 25 ft.
4) Increase cost per tower by $12,000.
5) Increase cost per tower by $8,000, for duct work for off gas treatment
6) Recomends Stainless steel towers ∴ add an additional 20% to the cost/tower
7) Due to vapor phase carbon treatment with an approximate PSI Drop of 15" water the Blower size would be ≈ 75 HP, force draft add ≈ 5000 onto cost of tower

This conversation took place on 7/25/94

∴ ≃ cost Stainless steel tower, Blower and off gas ductwork = $193,000.

HYDRO GROUP®

ENVIRONMENTAL PRODUCTS DIVISION

July 11, 1994

Mr. Chris Vaughan
ABB Environmental
110 Free Street
P.O. Box 7050
Portland, ME 04112-7050

Re: Air Stripping System Site

Dear Mr. Vaughan:

Thank you for your inquiry regarding water treatment equipment designed and manufactured by Hydro Group, Inc.

Per our recent telephone conversation and your fax transmittal dated July, 8 1994, you requested preliminary designs and budget prices for air stripping systems capable of removing 90% of Chloroform from a 3000 gpm to 12,000 gpm water stream at a minimum water temperature of 50°F.

Hydro Group proposes the following three system options to treat this water stream. Please refer to the attached Technical Bulletin for more specific details and dimensions of these units. The first option utilizes a single tower to treat 3000 gpm, the second option uses two 2 identical air strippers operating in parallel to treat 6000 gpm, the third option uses 4 air stripping towers operating in parallel to treat 12,000 gpm.

Model No:	PCS-145.20
Water Flow Rate Per Tower:	3000 gpm
Air to Water Ratio:	60:1
Air Flow Rate Per Tower:	24,000 cfm
Tower Diameter:	12.1'
Packed Bed Depth:	20'
Packing Type:	3.5" Tripacks
Overall Height:	33'
Approx. Blower BHp:	17 Hp
Blower Motor Size:	20 Hp
Total Budget Price 1 Tower:	$129,000 to $140,000
Total Budget Price 2 Towers:	$250,000 to $265,000
Total Budget Price 4 Towers:	$480,000 to $500,000

Each budget price includes a structural grade aluminum tower shell with a high build epoxy internal coating, standard tower internals, packing media, attached influent piping, a blower, ductwork between the tower and blower, and delivery to the jobsite. We do not include off-gas treatment, a control system, installation, sales tax, interconnecting piping, mechanical, electrical or general site work of any kind at this time.

The tower and blower will require a space approximately 15' wide by 22' long. The unit will require 230/460 Volt, 3 phase service. Off-gas will be required depending on the duration of operation per year and the concentrations. If the system requires off-gas treatment the blower will need to be larger, ductwork and dehumidifier will be required to discharge to an off-gas GAC vessel.

The system should be checked on periodically due to the possibility of scaling in the tower. The system should have a full inspection annually. An inspection requires rental of a man-lift and one full man-day per tower.

For a long term project, over 15 years, a stainless steel tower may be the best solution. Stainless steel towers have a longer life and have less maintenance than a system with an internal coating. The capital cost of a stainless steel tower is roughly 20% to 25% more than a coated aluminum tower.

If you have any questions or require additional information including detailed technical specifications or a formal proposal, please do not hesitate to call me. We are looking forward to working further with you on this project.

Sincerely yours,

HYDRO GROUP, INC.
Environmental Products Division

Kenneth S. Marran
Applications Engineer

KSM/mef
E94-7-11.ksm

HYDRO GROUP® Pre-Engineered Packed Column Air Strippers

Packed column air strippers, because of their efficiency and economics, have become a technology of choice for the removal of a broad range of volatile organic compounds (VOCs) and other dissolved gases from water. Hydro Group, Inc. uses its experience and extensive computer data base to pre-engineer a line of packed column air strippers. Single units in the line can handle flow rates as high as 3500 gpm.

Pre-engineered towers reduce engineering costs up to 25%, and pre-engineering can cut up to six weeks from the normal 14 to 18 weeks for custom design and construction.

PRE-ENGINEERED AIR STRIPPER BENEFITS

- **Reduced engineering costs up to 25%**
- **Delivery time reduced six weeks from the normal 14 to 18 weeks for custom design and construction**
- **Flow rates up to 3500 gpm**
- **VOC removal efficiencies for a broad range of compounds can exceed 99%**
- **Options help meet special site needs**

Construction

The packed towers are available in a wide variety of materials including aluminum, coated steel, stainless steel and fiberglass reinforced plastic (FRP). Metallic construction materials are usually recommended for the tower shell because they are structurally strong enough to be free-standing, have high resistance to sunlight and wide temperature fluctuations and require a minimum of maintenance.

The standard pre-engineered tower shells are constructed of structural grade aluminum. Each is designed to be anchored to a concrete pad, free-standing without any guy wires. All towers meet American National Standards Institute codes for snow, wind and seismic loading. Hydro Group utilizes superior packing exhibiting high removal efficiency accompanied by low hydraulic energy loss.

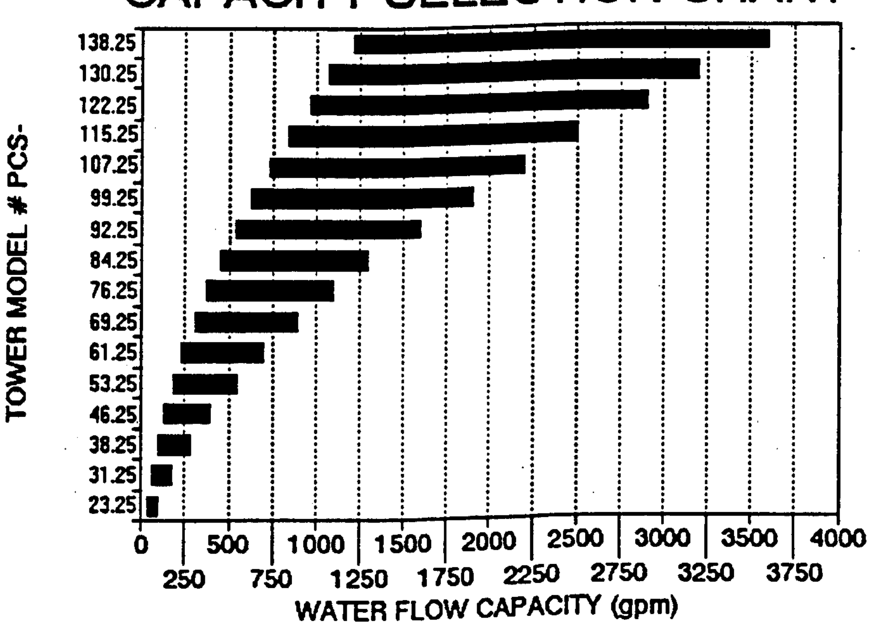
Removal efficiencies with pre-engineered air strippers, for a broad range of compounds—including VOCs, radon, carbon dioxide, hydrogen sulfide, etc.—can exceed 99%.

The design of the forced draft blower is based on the most efficient air-to-water ratio and headloss through the column. The blowers are designed for energy efficiency, quiet operation and outdoor use.

Nominal tower sizes range from 1.91 to 11.46 ft in diameter by 33 to 39 ft in height.

Standard equipment with the tower shell includes polypropylene packing, aluminum orifice plate distributor, polypropylene mist eliminator, FRP packing support tray and steel blower.

CAPACITY SELECTION CHART



Optional accessories

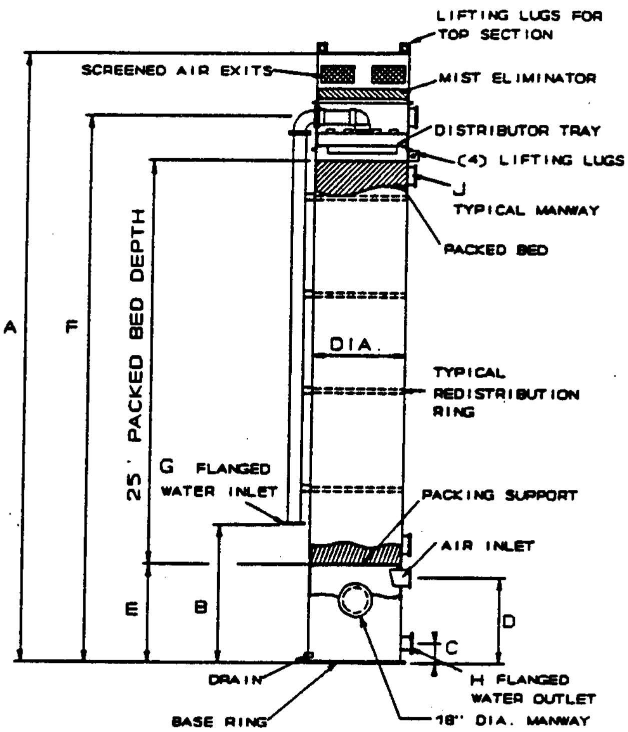
For specific site conditions, features can be added, including treatment of offgas, air inlet filters, a booster pump, control systems to interface with

continued on reverse

existing systems, foundations, power supply, mechanical interface, cleaning systems, and installation and startup services. Hydro Group can provide complete battery limit systems when desired.

Hydro Group manufactures its strippers of quality materials and components to insure durability and trouble-free operation.

For more information, call or write Hydro Group's Environmental Products Division.



How to use this table:

1. Locate the desired tower capacity on the horizontal axis of "Capacity Selection Chart" on the front of this bulletin.
2. Move vertically up to the horizontal bar.
3. Move to the left axis to select tower model.
4. Locate the model on the table below and fill in the dimensions of the tower.
5. Note that tower performance will vary with waterflow and compound; so call Hydro Group, Inc. for final sizing and cost quotations.

Hydro Group Model #PCS-	Nominal Tower Diameter (feet)	Dimensions								
		A[1,2] (feet)	B (inch)	C (inch)	D (inch)	E (inch)	F (ft/in)	G[1] (inch)	H (inch)	J (inch)
23.25	1.91	33	20	6.50	35.50	45	30'	3	4	12
31.25	2.55	33	20	6.50	35.50	45	30'	3	4	18
38.25	3.18	33	20	7.50	35.50	45	30'2"	4	6	18
46.25	3.82	34	20	9.75	35.50	45	30'6"	6	8	18
53.25	4.46	34	20	9.75	35.50	45	30'6"	6	8	18
61.25	5.09	34	20	9.75	35.50	45	30'6"	6	8	18
69.25	5.73	35	20	11.00	42.50	54	31'6"	8	10	24
76.25	6.37	35	20	11.00	42.50	54	31'6"	8	10	24
84.25	7.00	35	24	12.50	42.50	54	31'6"	10	12	24
92.25	7.64	35	24	12.50	42.50	54	31'6"	10	12	24
99.25	8.28	36	24	12.50	51.00	66	32'6"	10	12	24
107.25	8.91	36	36	13.50	51.00	66	32'6"	12	14	24
115.25	9.55	37	36	13.50	51.00	66	32'6"	12	14	24
122.25	10.19	38	36	13.50	57.00	75	33'0"	12	14	24
130.25	10.82	38'6"	36	14.75	59.00	75	33'9"	14	16	24
138.25	11.46	38'6"	36	14.75	59.00	75	33'9"	14	16	24

*Sump manway will be 12" in PCS-23.25.
[1]Based on maximum liquid loading.
[2]Based on maximum air to water ratio.

Note: The information given in this table is subject to change. It should be used as a guide for preliminary design only. All dimensions should be confirmed with Hydro Group, Inc. No responsibility is accepted by Hydro Group, Inc. or its representatives for any liability resulting from the use of this information.

Hydro Group, Inc.
Environmental Products Division
97 Chimney Rock Road
Bridgewater, NJ 08807

ABB
ASEA BROWN BOVERI

ABB Environmental Services, Inc.
110 Free Street
P.O. Box 7050
Portland, Maine 04112-7050
Telephone (207) 775-5400
Fax (207) 772-4762

TELEPHONE MEMORANDUM

PROJECT NO.: 6853-09 DATE: 7/18/94

CLIENT: Badger - FS

PROJECT DESCRIPTION:

BETWEEN: Carl Kraus Calgon Carbon Corp Chicago office (708) 505-1919

AND: C. Vaughn

SUBJECT: Aqueous and Vapor Phase Carbon Treatment systems

Aqueous Phase Carbon: Carl mentioned the following to treat 1000 gall/min:

MODEL 10

1. Need two 10 Ft Dia vessel in series (Model 10).
2. ≈ cost $160,000, includes initial carbon fill
3. Carbon usage rate ≈ 0.12 lb carbon / 1000 gall water treated
4. Carbon Regeneration Fee $1.00 / lb carbon (includes delivery)
5. Each vessel has 20,000 lbs of carbon
6. Approximate change out for each vessel every 1/2 year based on CCl_4 conc. (looking at the lead vessel only)

VAPOR Phase Carbon: Carl mentioned the following to treat
BPL mesh size 4x10 6000 CFM Air ⇒ Industrial air Purification

1. Need 1 unit 10ft diameter, 3.4 ft bed depth
2. 8000 lb carbon
3. unit cost $26,500 excluding carbon
4. Carbon usage rate = 10% wt by loading
5. Carbon Regeneration Fee $2.25 /lb

DISTRIBUTION:
ABB

6. Approximate Bed depth ≈ 3.4 ft
7. Approximate Changeout every 13 years based on CCl_4 conc.

Assume every 10 years

To Chris V.	From Karl Krause
Co. ABB Env.	Co.
Dept.	Phone #
Fax # 207 772-4762	Fax #

MODEL 10

CARBON ADSORPTION SYSTEM

DESCRIPTION

The Calgon Carbon Model 10 is an adsorption system designed for the removal of dissolved organic contaminants from liquids using granular activated carbon. The modular design concept allows selection of options or alternate materials to best meet the requirements of the site and treatment application.

The Model 10 system is delivered as two adsorbers and a compact center piping network, requiring only minimal field assembly and site connections. An optional mounting skid is available to facilitate installation. The pre-engineered Model 10 design assures that all adsorption system functions can be performed with the provided equipment.

The process piping network for the Model 10 accommodates operation of the adsorbers in parallel or series (with either adsorber placed in first stage). The piping can also isolate either adsorber from the flow. This permits carbon exchange or backwash operations to be performed on one adsorber without interrupting treatment.

The unique internal cone underdrain design provides for the efficient collection of treated water and the distribution of backwash water. The internal cone also insures efficient and complete discharge of spent carbon from the adsorber. The Model 10 system is designed for use with Calgon Carbon's closed loop carbon exchange service. Using special designed trailers, spent carbon is removed from the adsorbers and returned to Calgon Carbon for reactivation. The trailers also recharge the adsorbers with fresh activated carbon.

SYSTEM SPECIFICATIONS

Carbon adsorbers:

- Carbon steel ASME code pressure vessels.
- Internal vinyl ester lining (nominal 35 mil) where GAC contacts steel, for potable water and most liquid applications.
- Polypropylene slotted nozzles for water collection and backwash distribution.

Standard adsorption system piping:

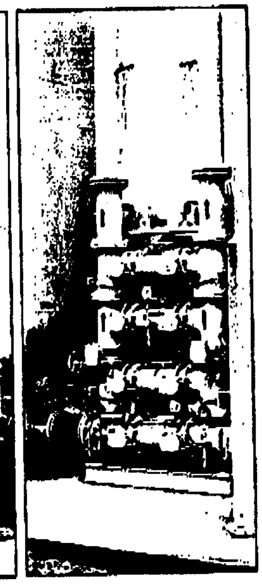
- Schedule 40 carbon steel process piping with cast iron fittings.
- Cast iron butterfly valves for process piping.
- PPL lined steel pipe for GAC discharge.
- Full bore stainless steel ball valves for GAC fill and discharge.

System external coating:

- Epoxy mastic paint system

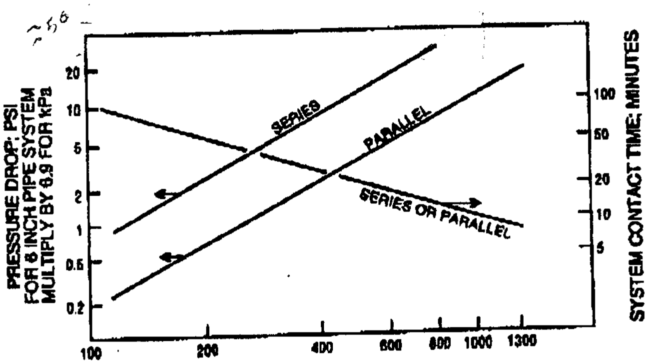
Available options:

- Unifying system skid.
- In-bed water sample collection probes.



OPERATING CONDITIONS

Carbon per adsorber:	20,000 lbs. (9080 kg)
Pressure rating:	125 psig (862 kPa)
Pressure relief:	Graphite rupture disk (94 psig)
Vacuum rating:	14 psig
Temperature rating:	150°F maximum (65°C)
Backwash rate:	Typical 1000 gpm (30% expansion)
Carbon transfer:	Air pressure slurry transfer
Utility air:	100 scfm at 30 psig (reduce to 15 psig for trailer)
Utility water:	100 gpm at 30 psig
Freeze protection:	None provided; enclosure or protection recommended

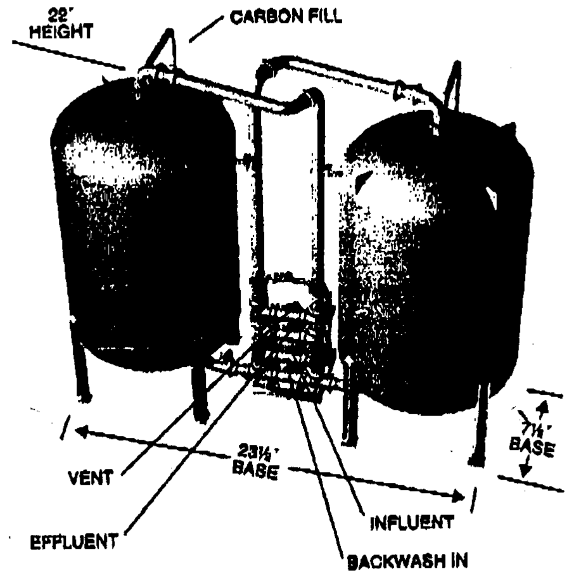


LE-ELT-06/93

CALGON CARBON CORPORATION • P.O. BOX 717 • PITTSBURGH, PA 15230-0717 • PHONE 1-800-4CARBON

DIMENSIONS AND FIELD CONNECTIONS

Adsorber vessel diameter: .... 10 ft (3050 mm)
Process Pipe: .... 6 in. or 8 in.
Process Pipe connection: .... 125# ANSI flange
Utility water connection: .... ¾ in. hose connection
Utility air connection: .... ¾ in. hose connection
Carbon hose connection: .... 4 in. Kamlock type
Carbon dry fill: .... top 8" nozzle
Backwash connections: .... 6 in. or 8 in. flange
Drain/vent connection: .... 6 in. or 8 in. flange
Adsorber maintenance access .. 20 in. round flanged manway
14 in. x 18 in. manway below cone
Adsorber shipping weight .... 18,500 lbs. (empty) (8400 kg)
System operating weight .... 215,000 lbs. (97,610 kg)



Model 10 Adsorption System

CAUTION

Wet activated carbon preferentially removes oxygen from air. In closed or partially closed containers and vessels, oxygen depletion may reach hazardous levels. If workers are to enter a vessel containing carbon, appropriate sampling and work procedures for potentially low-oxygen spaces should be followed, including all applicable federal and state requirements.

For detailed information on the products described in this bulletin, please contact one of our Regional Sales Offices located nearest to you:

New Jersey
Bridgewater, NJ 08807
Tel (908) 526-4646
Fax (908) 526-2467

Pennsylvania
Pittsburgh, PA 15230-0717
Tel (412) 787-6700
800/4-CARBON
Fax (412) 787-6676

Illinois
Lisle, IL 60532
Tel (708) 505-1919
Fax (708) 505-1936

California-North
San Mateo, CA 94404
Tel (415) 572-9111
Fax (415) 574-4466

Texas
Houston, TX 77040-6071
Tel (713) 690-2000
Fax (713) 690-7909

California-South
Carlsbad, CA 92008
Tel (619) 431-5550
Fax (619) 431-8169

Latin America/ Asia-Pacific
Pittsburgh, PA 15230-0717
Tel (412) 787-4519
Fax (412) 787-4523

Canada
Calgon Carbon Canada, Inc.
Mississauga, Ontario
Canada L4V 1N3
Tel (416) 673-7137
Fax (416) 673-8883

Europe
Chemviron Carbon
Brussels, Belgium
Tel 32 2 773 02 11
Fax 32 2 770 93 94

If at any time our products or services do not meet your requirements or expectations, or if you would like to suggest any ideas for improvement, please call us at 1-800-548-1999. From outside the U.S. please call +1-412-787-6700.

CALGON

CALGON CARBON CORPORATION

CALGON

TYPE BPL GRANULAR CARBON

MESH SIZES: 4 x 10, 6 x 16, 12 x 30

Type BPL Activated Carbon is designed for use in vapor phase applications, and is available in several mesh sizes to suit specific design requirements. It is made from selected grades of bituminous coal combined with suitable binders. These binders impart the superior hardness that is necessary for the long life expected in such applications. Produced under rigidly controlled conditions by high temperature steam activation, BPL Carbon provides high surface area, fine pore structure, high density, high volume activity and ease of regeneration.

Type BPL Carbon is used in all types of vapor phase adsorption. A typical use is solvent recovery where BPL is used for the adsorption and recovery of alcohols, chlorinated hydrocarbons, esters, ketones, ethers, hydrocarbons, and aromatics.

Type BPL is used almost universally as the catalyst support in the acetylene process for the production of vinyl chloride and vinyl acetate monomers. Here, high conversion rates and exceedingly long life mark its performance. It is also used as a direct catalyst in the production of phosgene and other similar reactions.

In fixed-bed adsorbers, Type BPL is used for the separation of hydrocarbon gas streams, such as the recovery of C_3 and C_4 cuts from natural gas. Similarly, organic sulfur, COS, and hydrocarbons are stripped from methane and hydrogen for catalytic conversion processes.

Other applications include purification of carbon dioxide for beverage use and dry ice; removal of chlorine, chlorinated organics and aromatics from anhydrous hydrogen chloride; purification of acetylene, hydrogen, compressed air, etc.

Air sterilization for aerobic fermentation can be accomplished with deep beds of BPL. It is widely used in air conditioning systems and for abatement of air pollution where plant air exhausts are odorous or harmful.

SCREEN SIZE SPECIFICATIONS, U.S. SIEVE SERIES TYPE BPL STANDARD MESH SIZES

4 x 10

Sieve No.	% Retained
+4	5 MAX
4 x 6	30-50
6 x 8	30-50
8 x 10	5-20
− 10	3.0 MAX

6 x 16

Sieve No.	% Retained
+6	5 MAX
6 x 8	30-50
8 x 12	30-50
12 x 16	10-25
− 16	5.0 MAX

12 x 30

Sieve No.	% Retained
+12	5 MAX
12 x 16	10-30
16 x 20	40-65
20 x 30	10-35
− 30	5.0 MAX

SPECIFICATIONS	4 X 10	6 X 16	12 X 30
Iodine Number, Minimum	1050	1050	1050
Carbon Tetrachloride Adsorption, Minimum, Weight %	60	60	60
Ash, Maximum, %	8	8	8
Moisture (as packed), Maximum, %	2	2	2
Hardness Number, Minimum	93	90	90
Apparent Density (Bulk Density, dense packing), g/cc, Minimum	0.47	0.47	0.48

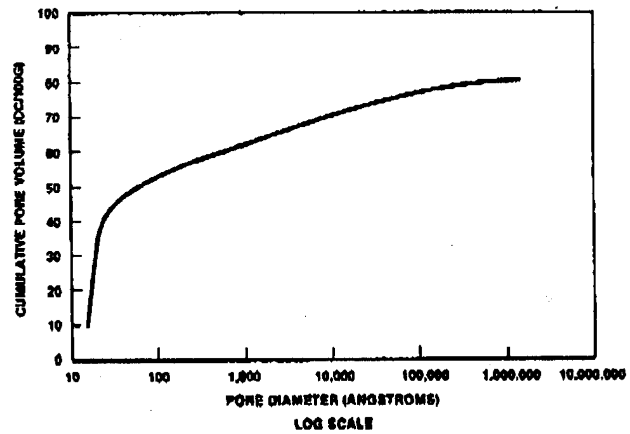
PORE STRUCTURE

The micropore structure of Type BPL carbon is illustrated at the right where the cumulative pore volume is plotted against pore diameter. The pore size distribution data are obtained from the water desorption isotherm.[1] Examination of the curve indicates that a large portion of this micropore volume is in pores of 15 to 20 Angstrom units in diameter. These small pores are accessible to all common gases and vapors, and therefore provide the maximum surface area for adsorption. The structure of the pores provides good retention of the adsorbed molecules while at the same time allowing high working capacities in systems providing for regeneration of the carbon.

In addition to the micropore structure, Type BPL is permeated by a system of macropores (pores larger than 1000 Angstroms in diameter) which serve as avenues for the rapid diffusion of gases to and from the micropore surfaces. This enhances both adsorption and reactivation characteristics.

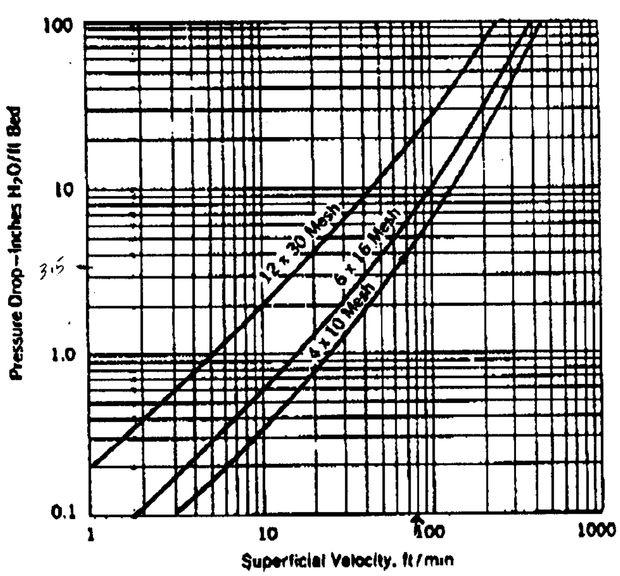
1. Juhola and Wiig: J. Am. Chem. Soc. 71, 2069 (1949)

PORE SIZE DISTRIBUTION
BPL 4 x 10



Typical Physical Properties:

Total Surface Area
(N_2, BET Method), m^2/g 1050-1150
Apparent Density (Bulk Density,
dense packing), Typical, g/cc 0.48
lb/ft^3 .... 30.0
Particle Density (Hg Displacement), g/cc 0.80
Real Density (He Displacement), g/cc 2.1
Pore Volume (Within Particle), cc/g 0.8
Voids in Dense Packed Column, % 43
Specific Heat at 100°C 0.25



COMMERCIAL INFORMATION

Shipping Points: Pittsburgh, Pennsylvania; Catlettsburg, Kentucky.

Mesh Sizes: 4 x 10, 6 x 16, and 12 x 30 U. S. Sieve Series.

Packaging: Packed in 55 gallon Leverpak drums, 200 lb. net, 217 lb. gross weight.

Bed Depth = 3.4 ft

PRESSURE DROP CHARACTERISTICS

Pressure drop, in inches of water per foot of bed depth, measured in air at 70° F. and 1 ATM, can be read above for standard mesh sizes of BPL Carbon. These data were obtained with a dense packing arrangement (30 lbs./ft.³) and should be used for design purposes.

Loose packed beds (26 lbs./ft.³) give a pressure drop approximately one-half of a dense bed. Pressure drop for other gases and higher pressures can be obtained from your Calgon Carbon Representative.

*For additional information,
contact the Calgon Carbon Corporation,
Box 717, Pittsburgh, PA 15230-0717
Phone: (412) 787-6700*

CALGON
CALGON CARBON CORPORATION

$Q = vA$

$Q = 6000\ ft^3/min$

$A = \pi(5)^2 = 78.5\ ft^2$

$v = \frac{6000}{78.5} = 76.4\ ft/min$

Pressure drop
$= 3.5\ (4ft) = 14.''\ H_2O$

Lee Ball Inc.

Route 3 W1730 Woodland Drive
Campbellsport, WI 53010

Fond Du Lac 414-533-5292 FAX 414-533-5390

QUOTATION

Date: 7-21-94
To: A.B.B. ENVIRONMENTAL SERVICES
Attn.: CHRIS Vaughan
Project:

Quote: BUDGET QUOTE

1 MODEL SBD-218-18-1902 HASTINGS DIRECT FIRED
- 18,000 CFM @ 1.25 TSP ; 1,902 MBH GAS
- ROOF CURB.
- INSULATED BLOWER
- 15 H.P. 460/3/60 MOTOR, STARTER & DIS. S/W
- WEATHER PROOFED.
- INTAKE HOOD & SCREEN.
- FILTER SECTION & 2" T.A. FILTERS.
- MOTORIZED DISCHARGE DAMPER.
- HI GAS PRESSURE REGULATOR
- FM CONTROLS.
- MS-14 ELECTRONIC DISCHARGE CONTROL.

CONTRACTOR ESTIMATED NET $14,560.00

YOU MIGHT USE A ROUGH BUDGET INSTALLED OF $14,560 × 2.2 = $32,048.00. DEPENDING ON AMOUNT OF DUCTWORK INVOLVED FOR DISTRIBUTION SYSTEM. WE RECOMMENT YOU USE A LAYOUT AND GET BIDS.

ABB
ASEA BROWN BOVERI

ABB Environmental Services, Inc.

110 Free Street
P.O. Box 7050
Portland, Maine 04112-7050

Telephone (207) 775-5400
Fax (207) 772-4762

TELEPHONE MEMORANDUM

PROJECT NO.: 06853-09 DATE: 7/25/94

CLIENT: Badger

PROJECT DESCRIPTION: SOPA phone (608) 356-065

BETWEEN: Larry Hawkins Wisconsin Light + Power Fax (608) 356-069

AND: C. Vaghn

SUBJECT: Power availability for off base treatment facility

Larry indicated:

1) There is a 12,400V / 3-Phase Line running along County-Z road

2) More Specific information would be needed for their distribution engineer to list the special accomodations that would be needed. In specific he mentioned

- Electrical Entrances needed
- general connected Load
- What types of motors
- What are the voltage requirements

DISTRIBUTION:
ABB

PROJECT Badger FS Size, model + cost of self Cleaning strainers	COMP. BY [illegible]	JOB NO.
	CHK. BY	DATE 7/15/94

Ref. Woodward-clyde 90% Design for on Base Treatment Facility (Woodward-clyde 1994b)

Make: Hayward®
The strainer Company™

Model: M 306L

Cost: ≈ $20,000

E-VII(2)

COMPARISON BETWEEN VARIOUS TYPES OF FILTERS

Cartridge filters, sand filters and automatic self cleaning strainers were compared to decide the most appropriate filtration equipment.
Fluid duty for the three comparisons was the same... 670 gpm water.
For the sake of comparison, the following models were considered typical for each type.

- Typical Cartridge Filter... "Pall Filters" Model # P38-4-SG29H13 consisting of 38 nos. of 40" long filter cartridges
- Typical Sand Filter..."IWT" Automatic backwash dual-media (sand + garnet) Filter Model # ADF-1440 (12 feet diameter x 5 feet high tank)
- Typical Automatic Self Cleaning Strainer... "Filtomat" Model M308 Inline Strainer

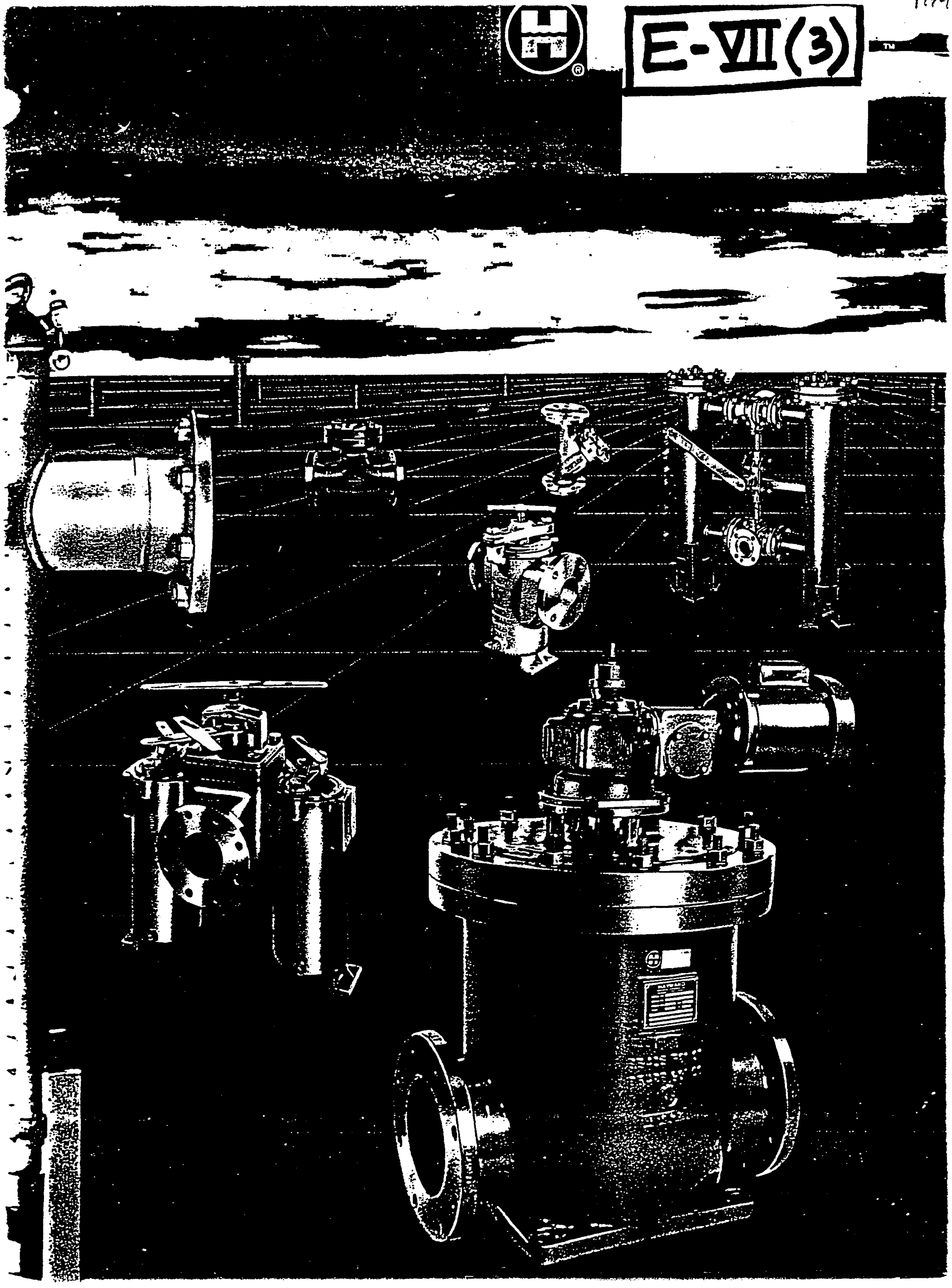
A comparison based on various basis is shown on the next page.

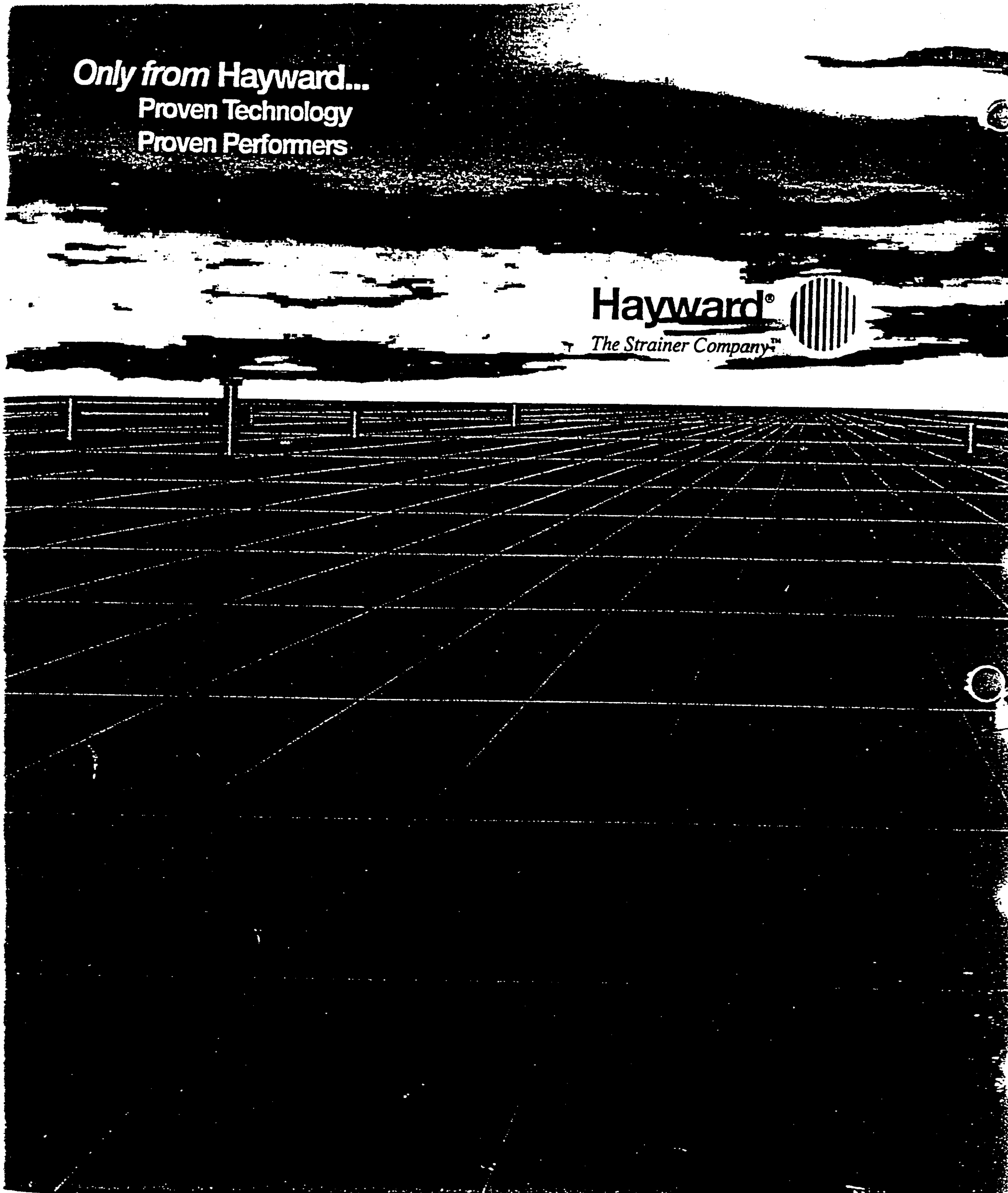
COMPARISON BETWEEN VARIOUS TYPES OF FILTERS

Comparison Basis	Bag or Cartridge Type	Sand Filter Type	Self Cleaning Strainer Type
Initial Cost	High initial cost (of the order of $ 100 K)	High initial cost (of the order of $ 50 K)	Low initial cost (of the order of $ 10-20 K)
Operating Cost	Replacement cost of filter elements (bags or cartridges)	No direct operating expense	No direct operating expenses
Energy Requirement	Operates at the expense of the fluid pressure drop (usually in the range of 3 to 30 psi).	Operates at the expense of the fluid pressure drop (usually in the range of 8 to 30 psi) plus power requirement for running backwash sequence.	Operates at the expense of the fluid pressure drop (usually in the range of 3 to 15 psi). Backwash uses the fluid pressure drop.
Space Requirement	Low space requirement	High space requirement	Low space requirement (Strainers are inline units)
Maintenance and Operator Attention	Frequent replacement of filter elements may be necessary. The unit must be opened, used filter elements removed and new filter elements replaced. Requires attention by operator.	For manually operated units, backwash sequence needs operator attention. Automatic units need little operator attention.	Automatic backwash sequence. Requires little operator attention.
Generation of Solid Waste	Generates the waste filter elements apart from the particulates removed.	Generates backwash solutions which are concentrated in solids content. Some means may be necessary to further concentrate the backwash to reduce the solid waste amount.	Generates backwash solutions which are concentrated in solids content. Some means may be necessary to further concentrate the backwash to reduce the solid waste amount.

obtained from (Woodward-Clyde, 1994b)

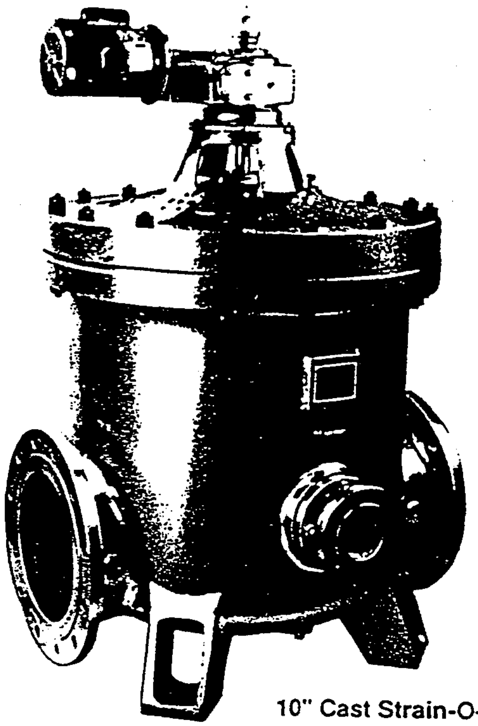
E-VII(3)



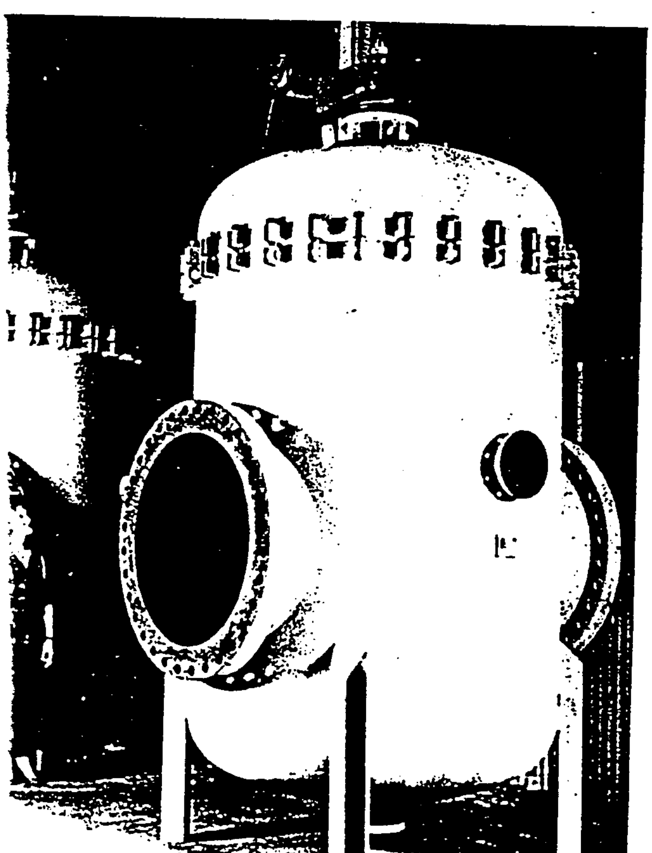

Only from Hayward...
Proven Technology
Proven Performers
Hayward®
The Strainer Company™

Hayward Strain-O-Matic® Self-Cleaning Strainers

Strain-O-Matic® Automatic Strainers



10" Cast Strain-O-Matic



Strain-O-Matic for power plant intake water service

DESIGN

The Hayward Strain-O-Matic is a motorized automatic self-cleaning strainer designed for the continuous removal of entrained solids from liquids in pipeline systems.

Strain-O-Matics have successfully performed in industrial, process, water and wastewater, power, paper and municipal applications for over 20 years.

With an automatic control system monitoring the strainer operation, cleaning is accomplished by an integral backwash system. A small portion of the screen element is isolated and cleaned by reverse flow. The remaining screen area continues to strain providing uninterrupted flow. With this efficient design, only a small amount of the liquid being strained is used to carry the concentrated debris away from the strainer.

The Strain-O-Matic is available in sizes 2" through 60" in cast or fabricated construction. Design and construction are in general accordance with ANSI and ASME Sec. VIII, Div. 1. A wide range of screen designs are offered, with openings as small as .0015 Inches/400 Mesh/38 Microns through 1/2 inch openings.

APPLICATION

Hayward's Strain-O-Matic self-cleaning strainers are commonly used on water service where the disposal of debris and backwash water is normally not a problem. Continuous flow is assured and protection is provided for nozzles, pumps, valves, heat exchangers and process equipment.

These units can also successfully handle other fluids such as white water, black liquor, starch, fuel and lubricating oil, caustic solutions and cooking oils. A determining factor in these cases is the recycling of the backwash fluid.

Strain-O-Matics will significantly reduce maintenance costs and provide uninterrupted flow. They are a particular worthwhile investment where the solids loading is high or upset conditions occur. Frequently, cleaning and servicing of manual strainers is costly, and if not properly attended, serious disruptions to the entire piping system can occur. Also, they are an ideal solution for maintenance problems where the strainer is in an inaccessible location.

Typical Applications

Strain-O-Matics are used in nearly every industry to strain fresh, brackish, or salt intake water for plant services; cooling, process, fire protection, etc.

Process Industry - Protect heat exchangers, pumps, valves and spray nozzles.

Power Industry - Strain water for cooling, pump seal water, traveling screen wash water.

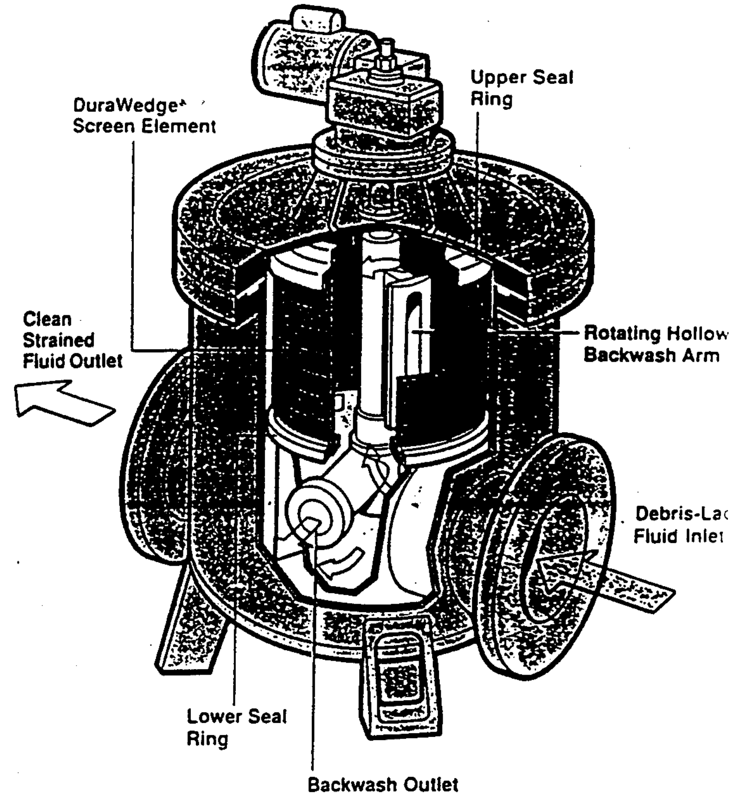
Pulp & Paper - Removing fibers from white water filtrate preventing clogging of nozzles. Separate bark and chips for recycling.

Sewage/Waste & Water - Straining secondary effluent thereby protecting spray nozzles while also providing clean plant service water.

Primary Metal Industry - Provide clean water for quenching, descaling, blast furnace cooling.

Marine/Offshore Platforms - Strain sea water for water flood in-

Model 596 Series Strain-O-Matic® Strainers



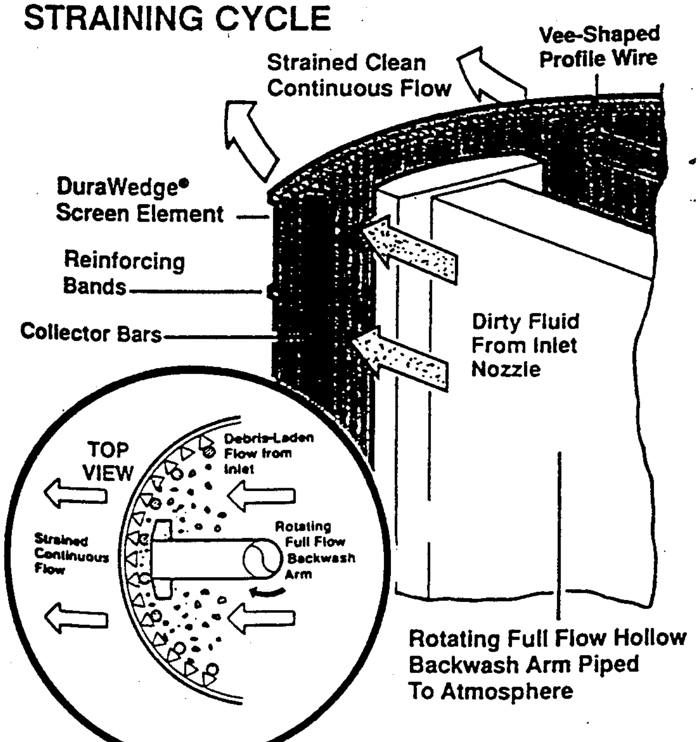
OPERATION

The debris-laden dirty fluid enters the strainer's large bottom chamber where the line velocity is reduced. Flow continues upward passing radially through the "sealed" screen element. Unwanted materials are trapped on the inside of the screen. The flow is uninterrupted and the strained clean fluid continues its path into the correctly proportioned outer annulus of the strainer body and exits through the outlet nozzle.

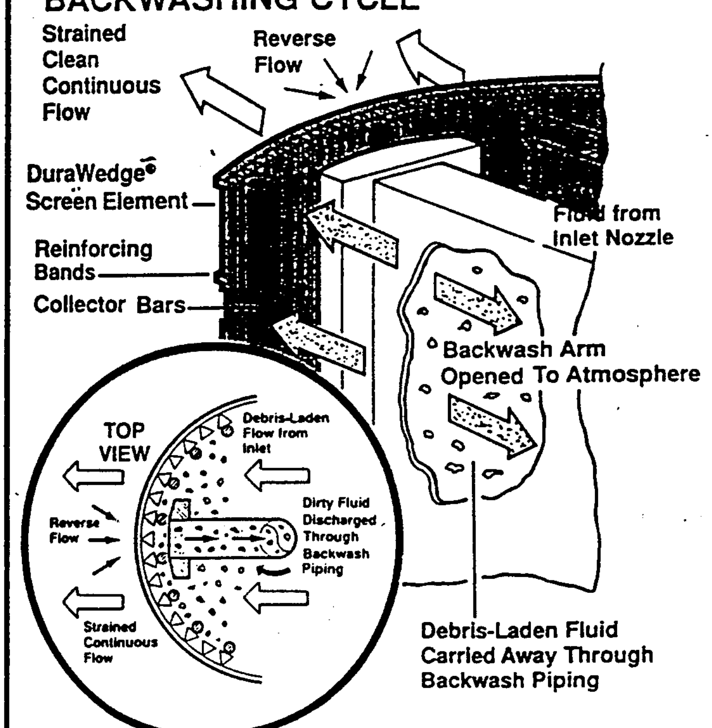
Backwash cleaning is accomplished by utilizing the pressure differential between line pressure and atmosphere. A hollow full flow backwash arm extending the full length of the screen element rotates slowly inside of the screen and is piped to atmosphere. The port shoe is in close proximity to the screen and its opening is equivalent to the "debris-collector" sections created by the convolutions and/or the vertical collector bars in the DuraWedge™ elements. When cleaning is required the automatic backwash valve opens the system to atmosphere causing a high velocity reverse flow across the isolated section of the screen. Dirt and debris are flushed from this segment of the screen into the backwash arm and out of the strainer via the backwash piping. During the backwashing cycle the main flow is uninterrupted and continues to be strained in the normal manner. A manual throttling valve is recommended after the control valve. Thus, backwash flow can be regulated and balanced for optimum performance and reduction of water loss.

An automatic control system consisting of an electrical panel, actuated valves and a differential pressure switch operates the strainer. The cleaning cycle can be set to "activate" by differential pressure and/or on a time cycle. The control system will automatically close the backwash valve after the screen element is properly cleaned. The unit can also be operated manually or in the continuous backwash mode.

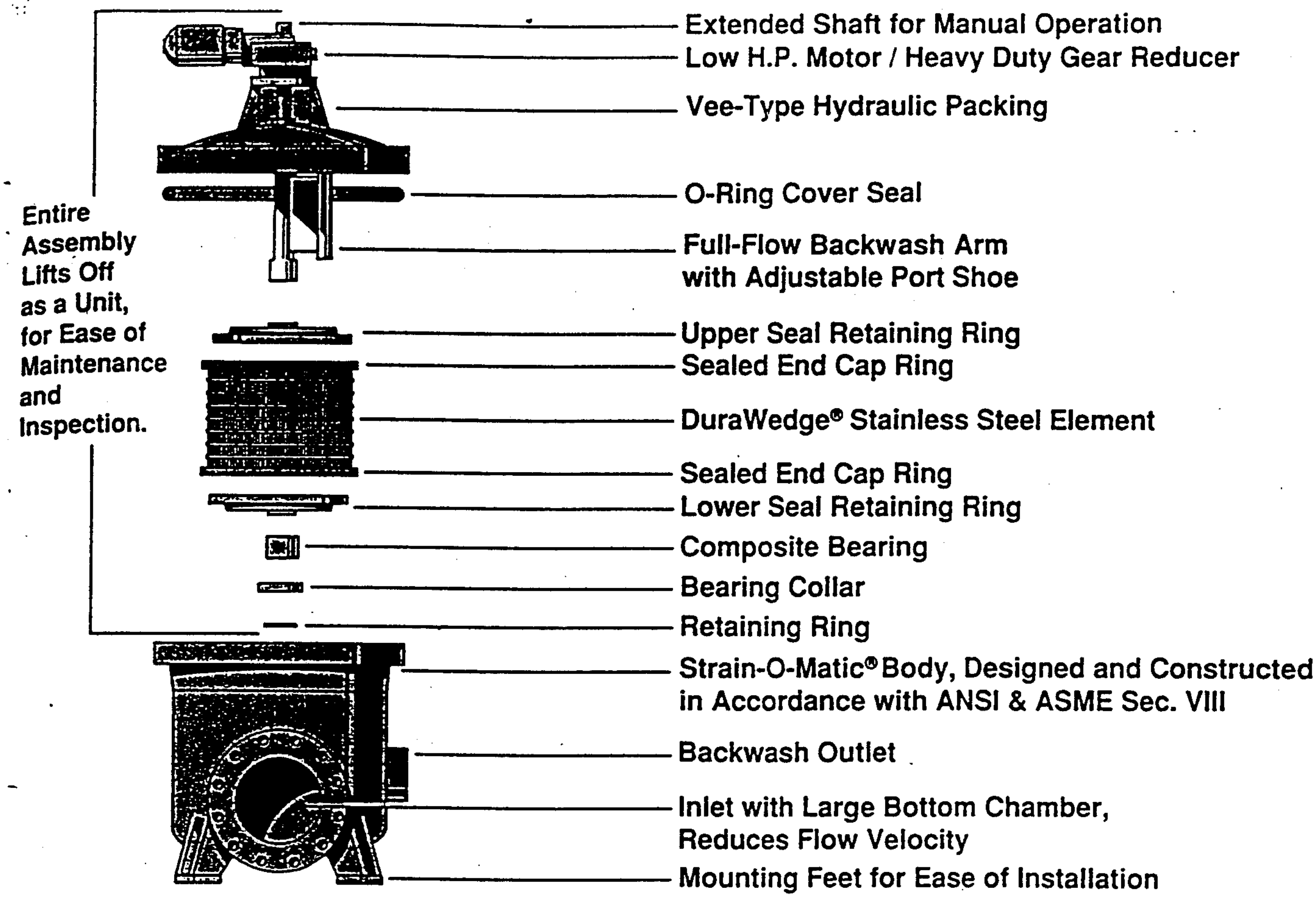
STRAINING CYCLE



BACKWASHING CYCLE



Hayward Strain-O-Matic® Self-Cleaning Strainers



FEATURES

- **Quality Construction:** Strain-O-Matics are designed & constructed in general accordance with ANSI and ASME Section VIII Div. 1. Code stamp available. Units can be furnished to meet 10CFR50 Quality Assurance requirements. Seismic qualification is also available.
- **Ease of Maintenance:** Unitized assembly - the motor, gear reducer, cover and complete internal operating mechanism lift off as a unit making all components easily accessible.
- **Low Backwash Fluid Requirements:** Due to the efficient hydraulic design of the backwash system.
- **Materials of Construction:** Cast 2" through 24" in Iron, Ductile Iron, Carbon and Stainless Steel, Ni-Resist, Aluminum Bronze. Fabricated 2" to 60" in Carbon Steel, Stainless Steel, Monel, Copper Nickel, etc.
- **Choice of Cartridge Screen Elements:** To suit the particular service - DuraWedge®, Perforated, Cartridge/Cage.
- **Minimal Power Consumption:** Only a 1/3 H.P. drive motor required in sizes thru 16", 1/2 H.P. - 18" thru 30", 1 H.P. for 36" and 42", 2 HP for 48", 54" and 60".
- **No Dirty Fluid By-Pass.** "Sealed End" cartridge screen element seat in close tolerance machined retained rings.
- **Tight, Simple Cover Seal:** O-Ring design permits resealing without time-consuming gasket replacement and adjustment.
- **Manual Operation if Required:** Utilizing extended shaft.

STRAIN-O-MATICS FOR SPECIAL APPLICATIONS

Suction Service:	Model 596LDP (Low Differential Pressure) Strain-O-Matic will perform efficiently on line pressures below 20 PSI, or even on the suction side of a pump.
Fine Straining:	Model 595FSD (Fine Straining Design) Strain-O-Matic is available with a unique Dual Cartridge/Screen element. Allows straining down to .0015 Inches/400 Mesh/38 Microns.
Water Conservation:	Model 596WCD (Water Conservation Design) Strain-O-Matic incorporates a Hayward Cyclone Separator which salvages a major portion of the backwash fluid for recirculation back to the main system.

Hayward Strain-O-Matic Self-Cleaning Strainer

Model 596 Cast Strainers

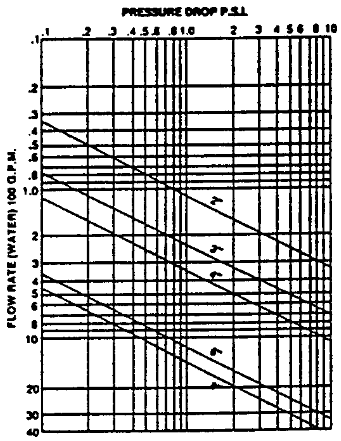
Sizes 2" Thru 8"

Application Limits

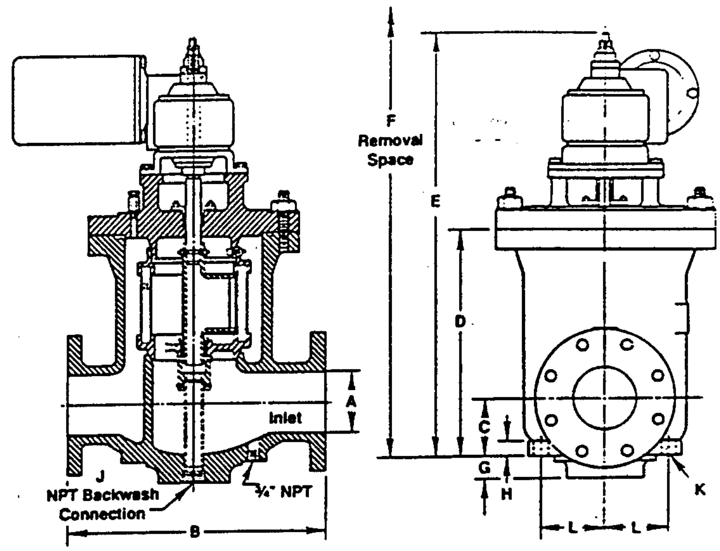
Cast Iron Class 125 Flange (-20° to 150°F) 150 psi
Cast Steel Class 150 Flange (-20° to 100°F) 150 psi
Cast Steel Class 300 Flange (-20° to 150°F) 300 psi
Based on ratings of ANSI and ASME, Section VIII, Div. 1.
Lower pressure ratings at higher temperatures.

Optional Features

- Stainless steel, copper nickel, monel, aluminum bronze and other materials of construction.
- ASME Section VIII, Div. 1 code stamp available.
- Mounting stand
- Flanged, screwed or socket weld backwash connections (steel unit only).



Pressure drop data indicates results to be expected with clean water, under normal flows, with standard straining media and in a clean strainer.



Approximate Dimensions (inches) **Approximate Wts. (lbs)**

A Size	B 150#	B 300#	C	D	E	F	G	H	J	K	L	Dry	Wet	Co
2"	17½	18⅛	3⅞	15⅛	28	37	1⅜	1	1	¾	4³⁄₁₆	285	320	12
3"	17½	18⅛	3⅞	15⅛	28	37	1⅜	1	1	¾	4³⁄₁₆	285	320	12
4"	17½	18⅛	3⅞	14⅞	28	37	1⅜	1	1	¾	4³⁄₁₆	290	325	12
6"	28	28⅞	6⅛	22⅝	39	50	1⅞	1¼	1½	1⅛	7½	1.200	1,375	43
8"	26	27	6⅛	22⅝	39	50	1⅞	1¼	1½	1⅛	7½	1.200	1,375	43

These dimensions are for reference only. For installation purposes, request certified drawings.

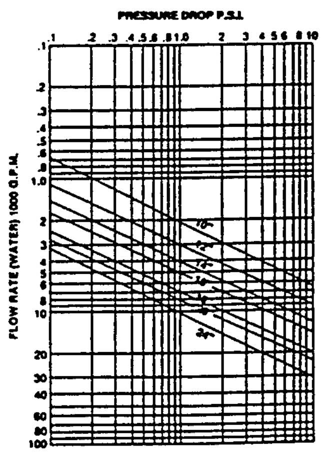
Sizes 10" Thru 24"

Application Limits

Cast Iron Class 125 Flange (-20° to 150°F) 150 psi
Cast Steel Class 150 Flange (-20° to 100°F) 150 psi
Cast Steel Class 300 Flange (-20° to 150°) 300 psi
Application Limits 24" Size
Ductile Iron Class 125 Flange (-20° to 150°F) 150 psi
Based on ratings of ANSI and ASME Section VIII, Div. 1. Lower pressure ratings at higher temperatures.

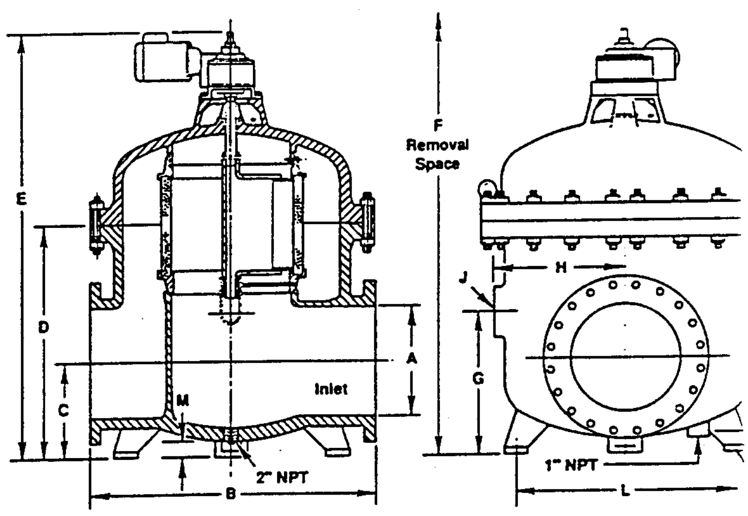
Optional Features

- Stainless steel, copper nickel, monel, aluminum bronze and other materials of construction.
- ASME Section VIII, Div. 1 code stamp available.
- Flanged, screwed or socket weld backwash connections (steel unit only).



Pressure drop data indicates results to be expected with clean water, under normal flows, with standard straining media and in a clean strainer.

Specific descriptions and construction details illustrated may vary slightly from equipment furnished. We reserve the right to revise or discontinue equipment or design features without notice. We recommend that you review performance and application data with us prior to final design.



Approximate Dimensions (inches) **Approximate Wts.**

A Size	B 150#	B 300#	C	D	E	F	G	H	J	K	L	M	P	Dry	Wet
10"	38¼	39⅝	11¼	31	54	74	15¼	15½	3	⅞	24½	2½	4¼	1,950	2,750
12"	36¼	37¾	11¼	31	54	74	15¼	15½	3	⅞	24½	2½	4¼	2,000	2,800
14"	44	45½	13¼	33½	55½	81¼	19¼	18½	3	⅞	30¼	2½	4½	2,800	3,850
16"	44	45½	13¼	33½	55½	81¼	19¼	18½	3	⅞	30¼	2½	4½	2,900	4,000
18"	53	–	16⅛	39¾	71½	84¾	24⅜	22⅛	3	⅞	37¼	2½	5⅛	6,075	7,975
20"	50	–	16⅛	39¾	71½	84¾	24⅜	22⅛	3	⅞	37¼	2½	5⅛	6,100	7,800
24"	64	–	18¾	53¾	90	113	27⅜	27¼	4	1⅛	47½	4	7⅞	6,800	12,800

These dimensions are for reference only. For installation purposes, request certified drawings.

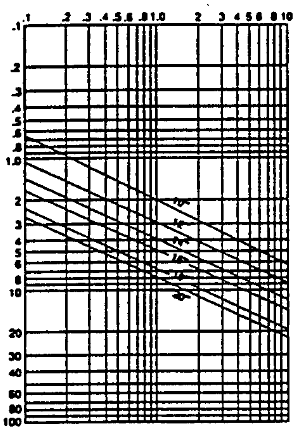
Hayward Strain-O-Matic® Self-Cleaning Strainers

Model 596
Fabricated Carbon Steel

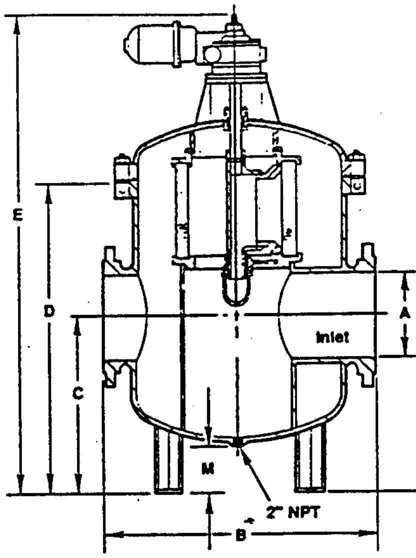
Sizes 10" Thru 20"

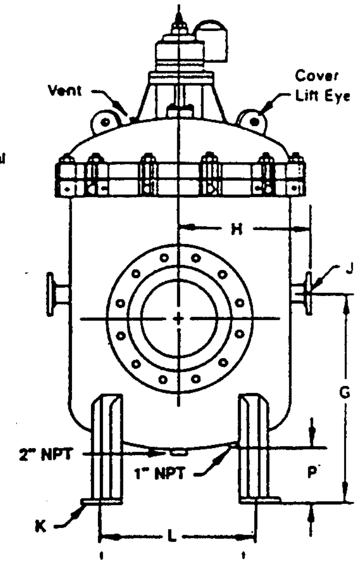
Application Limits
Fabricated strainers are designed within the limits of the customer's specifications and design criteria along with any applicable code requirement. i.e. ASME Section VIII Div. 1.

Optional Features:
- Stainless Steel, copper nickel, monel, aluminum bronze and other materials of construction.
- ASME Section VIII, Div. 1 code stamp available.
- Flanged, screwed or socket weld backwash connections (steel unit only).



Pressure drop data indicates results to be expected with clean water, under normal flows, with standard straining media and in a clean strainer.





Approximate Dimensions (inches) — Approximate Wts. (lbs.)

A Size	B 150#	B 300#	C	D	E	F	G	H	J	K	L	M	P	Dry 150#	Wet Design	Cover Only
10	34	34	23½	39¼	65½	77½	27¼	16	3	⅞	24	8	10⅜	1060	1695	414
12	34	34	25¼	42	68¼	80¼	30½	16	3	⅞	26	8	10³⁄₁₆	1225	2050	440
14	46	46	28	45³⁄₁₆	71⁹⁄₁₆	83½	33	21	3	⅞	32	8	10⅛	1720	3045	600
16	46	46	30	48³⁄₁₆	75¹⁄₁₆	86½	36⅝	21	3	⅞	34	8	9⅞	1890	3470	635
18	50	50	35¼	57¾	91⅛	106	42¼	23	3	1⅛	38	8	10¾	2595	5000	860
20	50	50	36¼	59¾	93⅜	108	44⅞	23	3	1⅛	40	8	10½	2775	5525	890

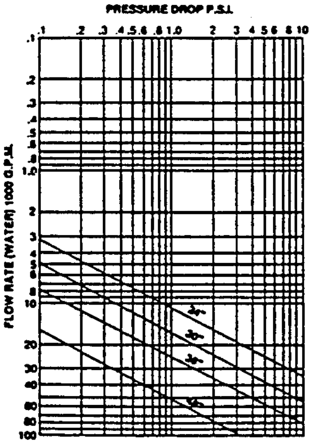
Note: J Backwash Outlet Flange Size. K Diameter Bolt Hole (4) Required 90° Apart.
L Diameter Bolt Circle.

These dimensions are for reference only. For installation purposes, request certified drawings.

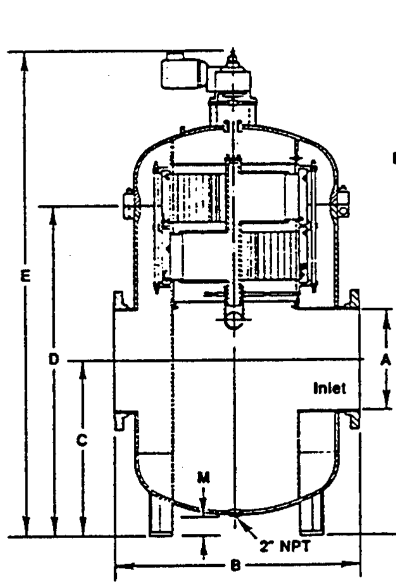
Sizes 24" Thru 48"*

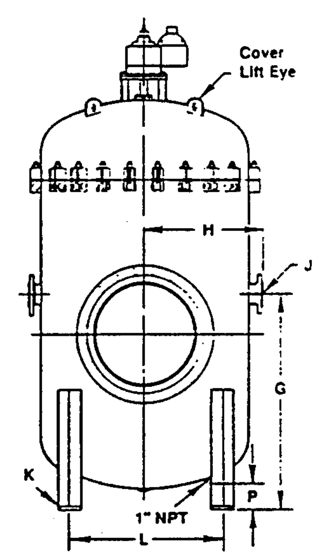
Application Limits
Fabricated strainers are designed within the limits of the customer's specifications and design criteria along with any applicable code requirement. i.e. ASME Section VIII Div. 1.

Optional Features:
- Stainless Steel, copper nickel, monel, aluminum bronze and other materials of construction.
- ASME Section VIII, Div. 1 code stamp available.
- Flanged, screwed or socket weld backwash connections (steel unit only).



Pressure drop data indicates results to be expected with clean water, under normal flows, with standard straining media and in a clean strainer.





Approximate Dimensions (inches) — Approximate Wts. (lbs.)

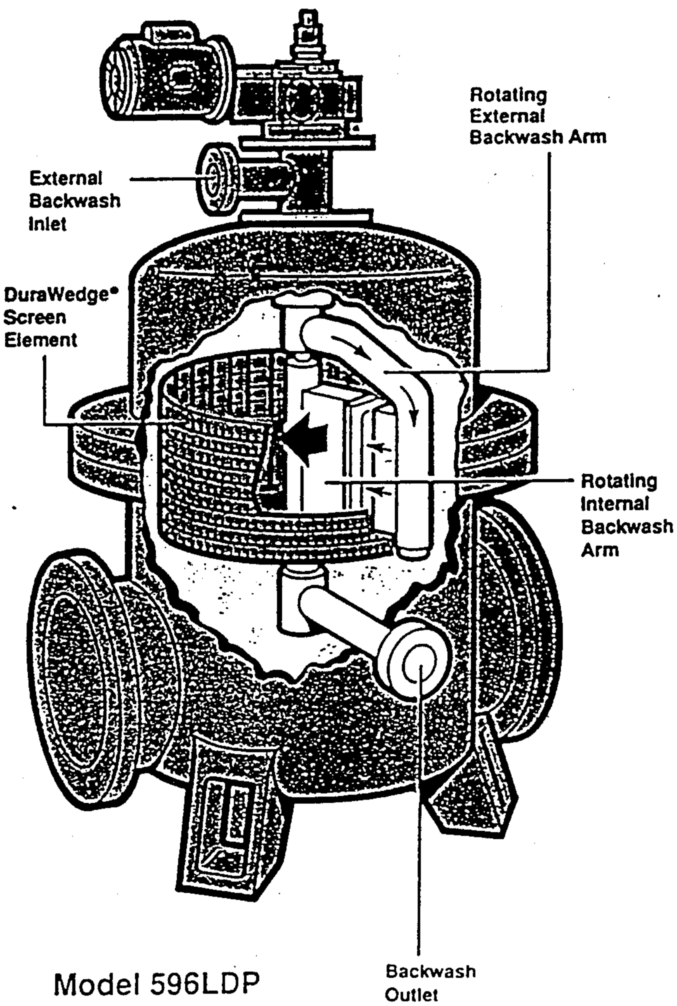
A Size	B 150#	C	D	E	F	G	H	J	K	L	M	P	Dry	Wet	Cover
24	58	41¼	77⅛	114	137	50¹¹⁄₁₆	27	4	1⅛	48	8	11¼	4,400	9,400	1,600
30	76	53¾	94¼	135¼	170	65¾	33	4	1⅜	60	8	10	8,500	17,900	2,750
36	90	60	101¾	148⅝	182	72¾	40	6	1⅜	66	8	14	14,000	29,530	4,500
48	109¼	62¾	122	177	227	80	48¾	8	1½	90	8	13	24,000	53,000	8,000

Note: J Backwash Outlet Flange Size. K Diameter Bolt Hole (4) Required 90° Apart.
L Diameter Bolt Circle.

These dimensions are for reference only. For installation purposes, request certified drawings.

...descriptions and construction details ... may vary slightly from equipment ... We reserve the right to revise or ... equipment or design features ... notice. We recommend that you review ... performance and application data with us prior to final design.

Model 596LDP (Low Differential Pressure) Cast and Fabricated



Model 596LDP

Sizes 2" Thru 60"

For suction service and line pressures less than 20 PS

Previously, self-cleaning strainers had to be located whe line pressures were above 20 PSI. Now, with the Haywa Strain-O-Matic LDP they can be utilized with line pressur below 20 PSI and can be placed in more convenient loc tions, even on the suction side of a pump. Thus pumpir equipment is also protected from damage by entrain debris.

DESIGN AND OPERATION

The Model 596LDP Strain-O-Matic configuration and ope tion is similar to the standard Model 596. However, it inc porates an external flushing arm which is attached to t same shaft and motor that drives the regular backwash ar The two components rotate synchronously.

The external backwash flushing arm directs a high veloc flow of liquid directly across the element into the opening the standard backwash arm. The impinged material trapp on the strainer screen is loosened and washed away throu the backwash outlet. The action is a "push-pull" effect sin the backwash arm is open to atmosphere.

The external backwash fluid should be at a minimum 20 F greater than the system operating pressure. This backwa fluid can be city water, plant service water or a side stre taken from the pressure side of the strainer line. In rem locations a small booster pump will do the job.

The automatic control system monitors the operation of t strainer. Activated by a differential pressure setting and time cycle, the external backwash inlet valve is opened at t same time as the backwash outlet valve, initiating the bac wash cycle. Only a small amount of external backwash fl is required. This is an extremely effective method of disloc ing dirt from the screen element. Continuous flow is ma tained at all times.

FEATURES

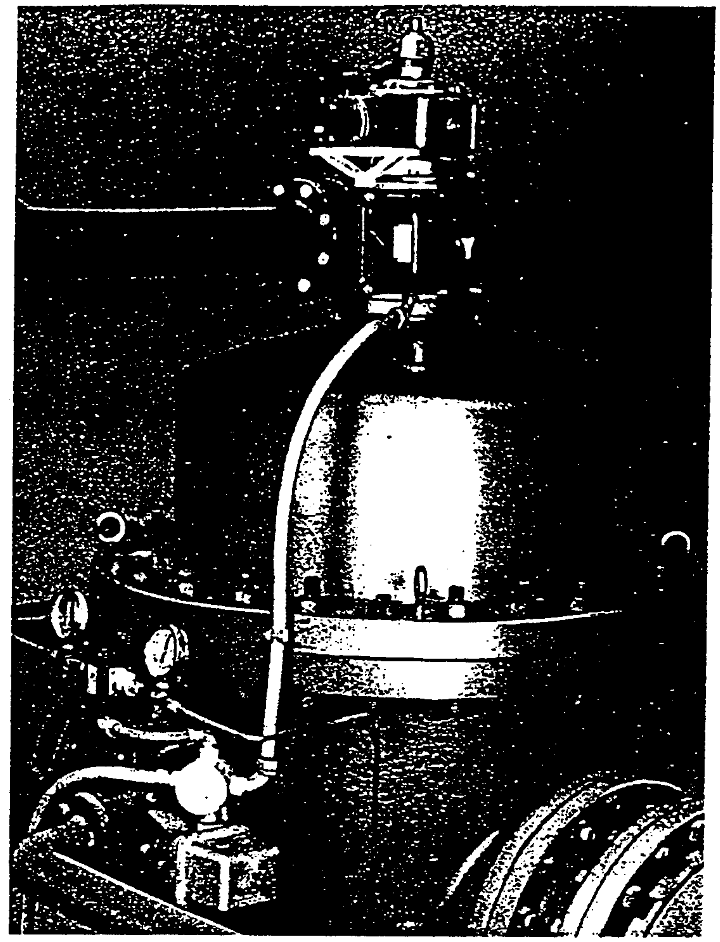
- **Quality Construction:** Designed and constructed in general accordance with ANSI and ASME Sec. VIII Div. 1. Code stamp available. Can also be furnished to meet the requirements: 10CFR50 Quality Assurance Program.
- **Materials of Construction:** 6" thru 24" in Iron, Ductile Iron, Stainless Steel, Monel, Aluminum Bronze. Fabricated 2" thru 60" in Carbon Steel, Stainless Steel, Monel, Copper Nickel. Flanged Connections, ANSI Class 125#, 150#, 300#.
- **Compact Design:** Same configuration as the standard Strain-O-Matic. Face to face and center line to bottom dimensions are the same. Overall height and clearance increase marginally. Also incorporates unitized desig feature. Motor, gear reducer, cover and complete intern operating mechanism lift off as a unit for ease of inspectic and maintenance.

Model 596LDP (Low Differential Pressure) Cast and Fabricated

APPLICATION

- Irrigation water where low head pressure is commonly encountered.
- Fire protection/general service water from ponds, lakes, etc.
- Cooling water for commercial buildings on suction side of pumps.
- Secondary effluent in treatment plants for spray nozzles, service water.
- Intake cooling water for power plants and industrial plants from rivers, bays, etc. where head variations occur.

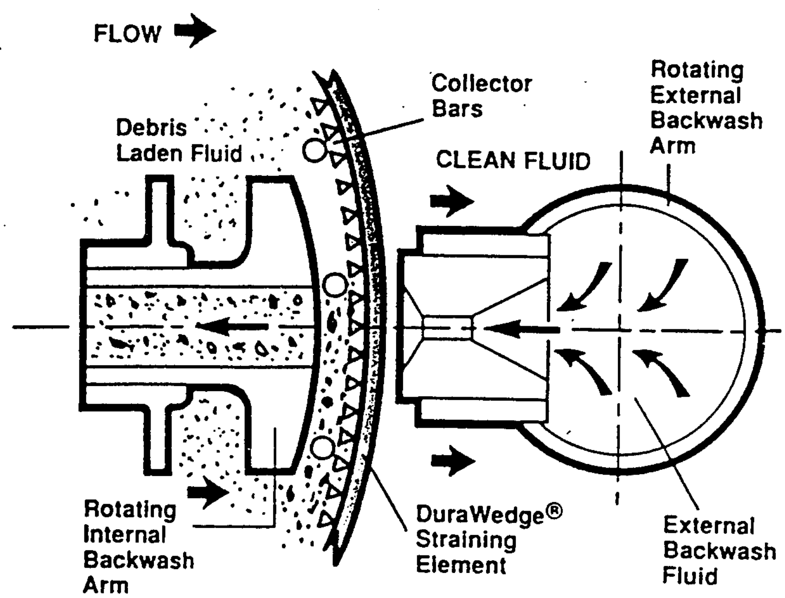
For dimensions refer to Model 596. Body configuration and dimensions are the same. Cover design is modified and overall height and clearance increase marginally.

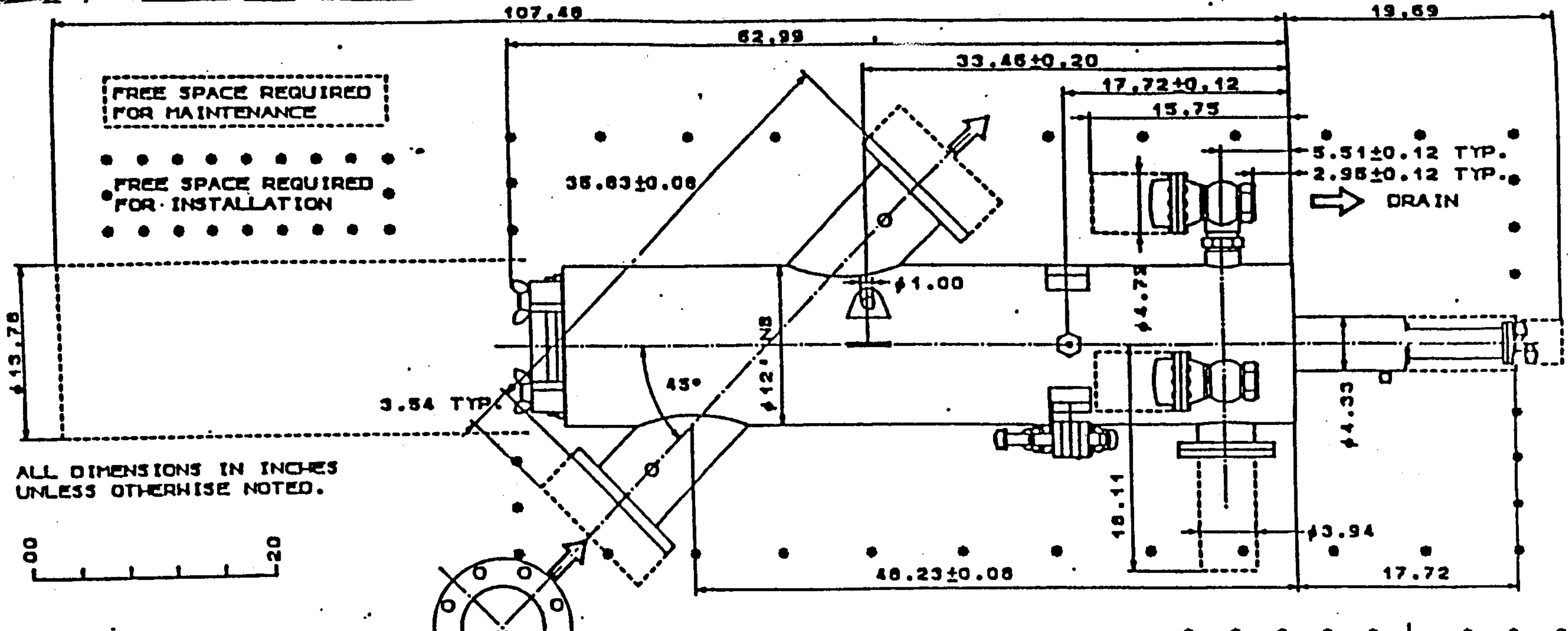


20" Cast Iron Model 596LDP Strain-O-Matic on-line in a public utility straining raw river water used for plant cooling service.

Top View of External Backwash Flow

High velocity external backwash is directed across the screen. Dirt, fibers, debris are dislodged and carried into the backwash arm and flushed away through the backwash outlet.





ALL DIMENSIONS IN INCHES
UNLESS OTHERWISE NOTED.

DATA M306L

NOMINAL FLOW RATE: 660 USGPM/ 550 IGPM

SCREEN AREA AVAILABLE:
FLAT MESH: 474 SQUARE INCHES
ZIG-ZAG MESH: 1426 SQUARE INCHES

SCREENS AVAILABLE:
FLAT SCREEN: 50,80,100,120,150,200,
400,800,1500,3000 MICRON
ZIG-ZAG SCREEN: 15,25,30,40,50,80,
100,120,150,200 MICRON

MAXIMUM WORKING PRESSURE: 150 PSIG

MINIMUM UPSTREAM LINE PRESSURE
REQUIRED DURING RINSE CYCLE: 30 PSIG

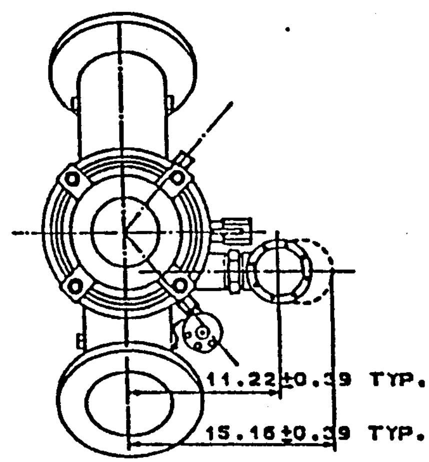
MAXIMUM WORKING TEMPERATURE: 150° F..

APPROXIMATE RINSE CYCLE TIME: 8-18 SEC.

INLET/OUTLET FLANGES: 6" NB ASA 150, BST'E',
DIN 10, JIS K10, OTHERS

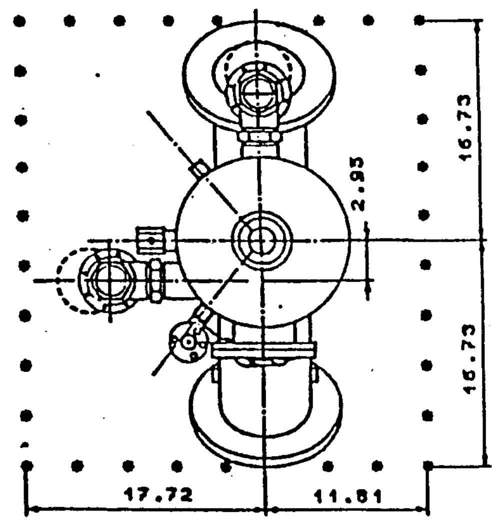
DRAIN LINE CONNECTION: 2" BSP OR NPT
MAIN DRAIN HEADER MUST BE
MINIMUM 3" NOMINAL BORE.

APPROX. WEIGHT: EMPTY 260 LBS.
FULL OF WATER 550 LBS.



VIEW ON COVER END

INLET



VIEW ON PISTON END

OUTLET

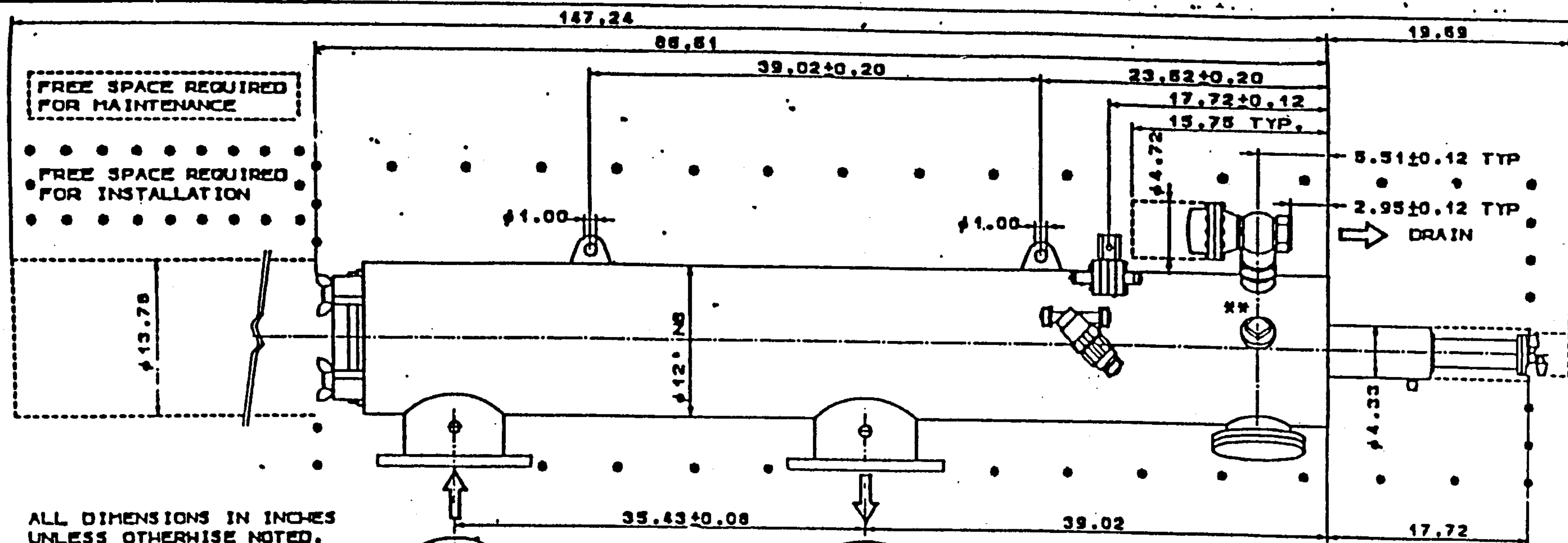
FILTOMAT AUTOMATIC
SELF-CLEANING FILTER

M306L

FILTOMAT Inc.

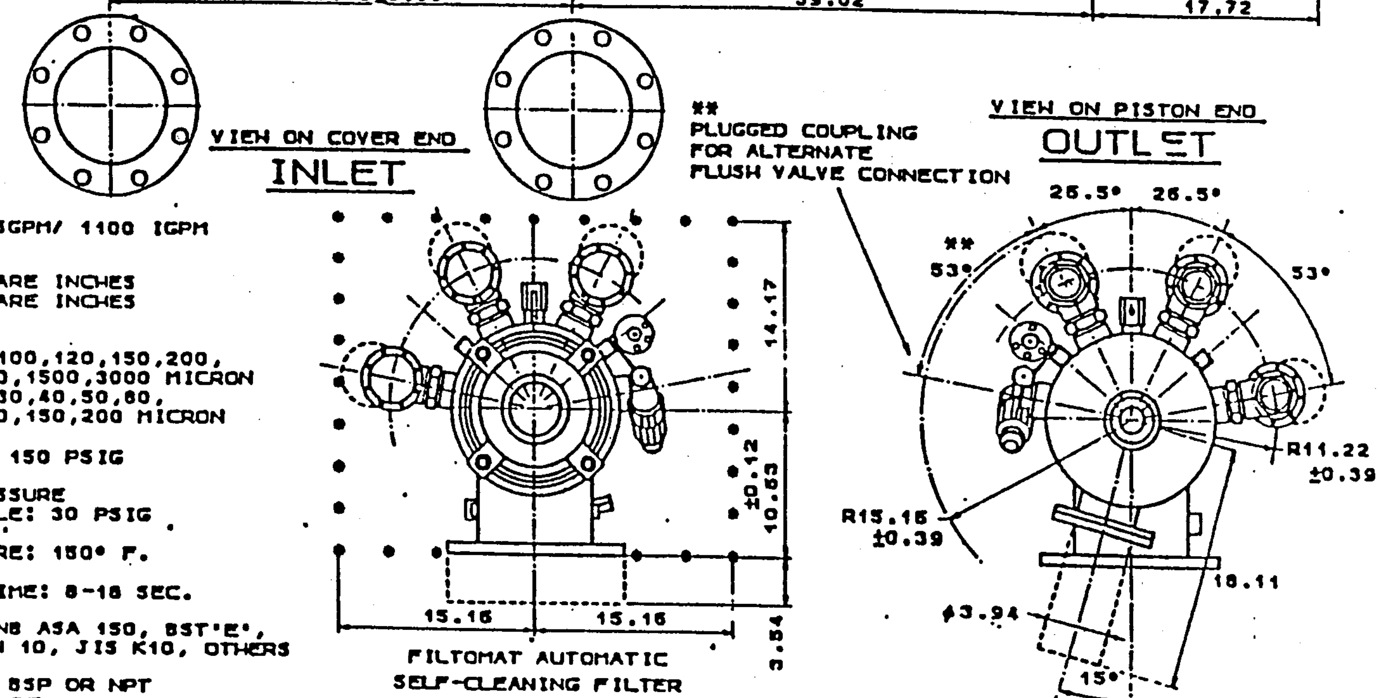
DATA SHEET (INCH) DRW 0700730

Blowdown 250 gpm/10 sec. = 41.7 gal per cycle
clean ΔP = ~1.5 psi
~~[illegible]~~ Dirty ΔP = 10 TO 13 psi



ALL DIMENSIONS IN INCHES
UNLESS OTHERWISE NOTED.

0 — 20



FILTOMAT AUTOMATIC
SELF-CLEANING FILTER

DATA M308LP

NOMINAL FLOW RATE: 1320 USGPM/ 1100 IGPM

SCREEN AREA AVAILABLE:
FLAT MESH: 713 SQUARE INCHES
ZIG-ZAG MESH: 2139 SQUARE INCHES

SCREENS AVAILABLE:
FLAT SCREEN: 50,80,100,120,150,200, 400,800,1500,3000 MICRON
ZIG-ZAG SCREEN: 15,25,30,40,50,80, 100,120,150,200 MICRON

MAXIMUM WORKING PRESSURE: 150 PSIG

MINIMUM UPSTREAM LINE PRESSURE
REQUIRED DURING RINSE CYCLE: 30 PSIG

MAXIMUM WORKING TEMPERATURE: 150° F.

APPROXIMATE RINSE CYCLE TIME: 8-15 SEC.

INLET/OUTLET FLANGES: 8" NB ASA 150, BST'E', DIN 10, JIS K10, OTHERS

DRAIN LINE CONNECTION: 2" BSP OR NPT
MAIN DRAIN HEADER MUST BE
MINIMUM 4" NOMINAL BORE.

APPROX. WEIGHT: EMPTY 352 LBS.
FULL OF WATER 705 LBS.

M308LP

FILTOMAT, INC.,

DATA SHEET (INCH) DRW 0700930

Blowdown 325 gpm/15 sec = 81.25 gal per cycle
clean ΔP = ~3 psi
Dirty ΔP = ~ 10 to 13 psi

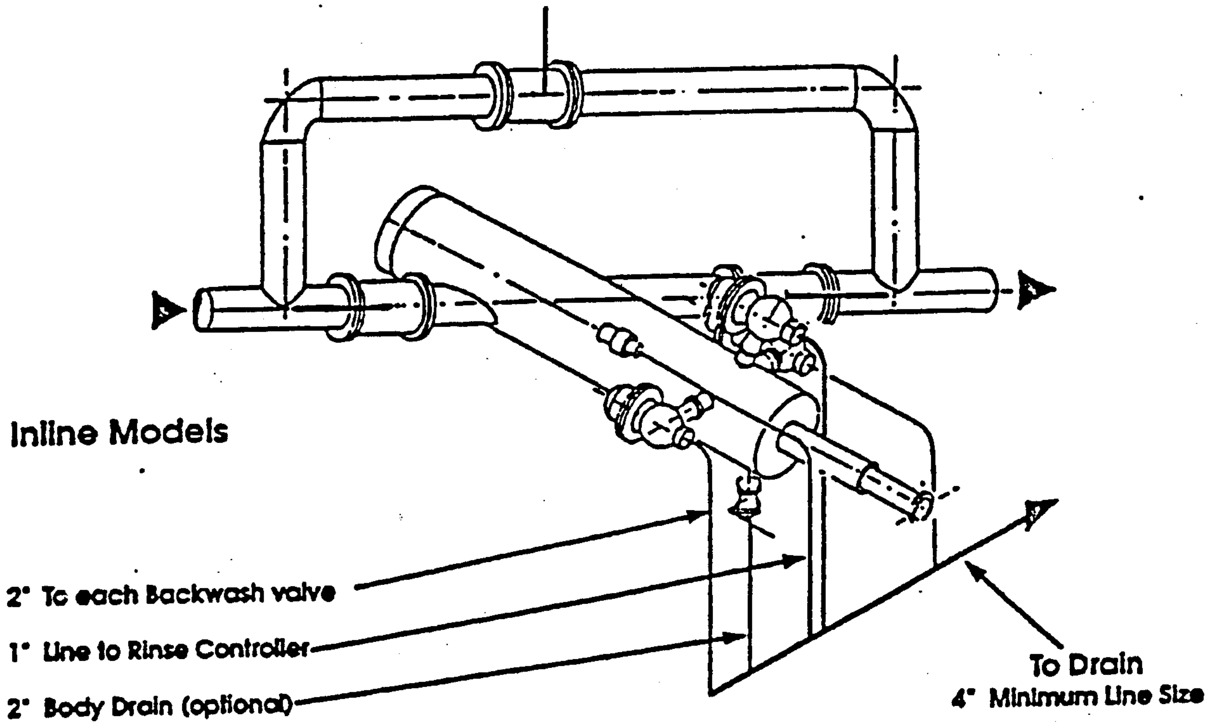
FILTOMAT™

It takes care of itself.

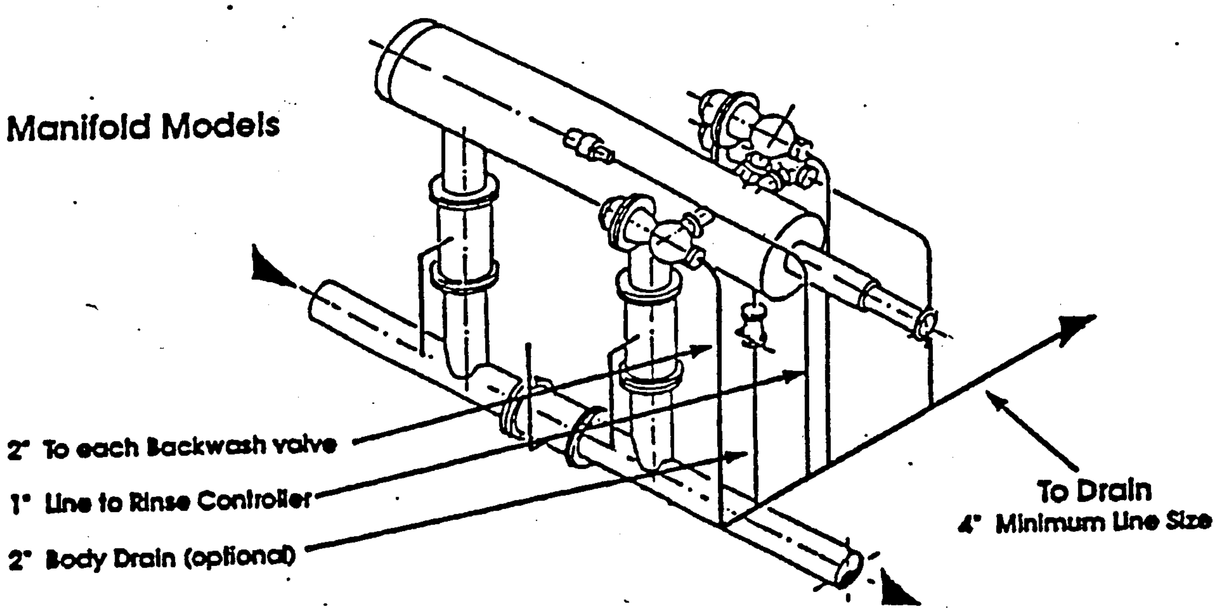
Filtomat

Installation and Drain Details

Inline Models



Manifold Models



Obtained from (Woodward-Clyde 1994b)

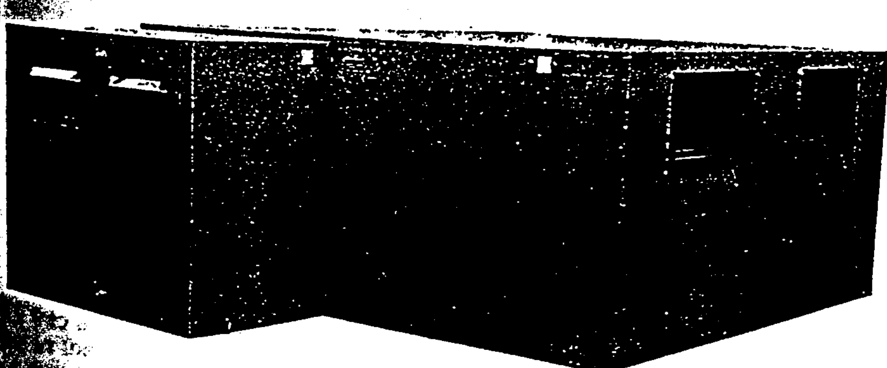
Hastings

Bulletin SBD-1
Dated May 1993
Supersedes SBD-1
December 1990

Directflow
SBD series

DIRECT GAS-FIRED MAKE-UP AIR SYSTEMS

Cooling Can Be Added



A MODEL FOR EVERY APPLICATION

SBD
DIRECT GAS-FIRED MAKE-UP AIR HEATERS

APPROVED
Units Available

SBDF
DIRECT GAS-FIRED DUCT FURNACES

AIR DELIVERIES FROM 2,000 TO 75,000 SCFM. HEAT INPUT FROM 94 TO 10,565 MBH

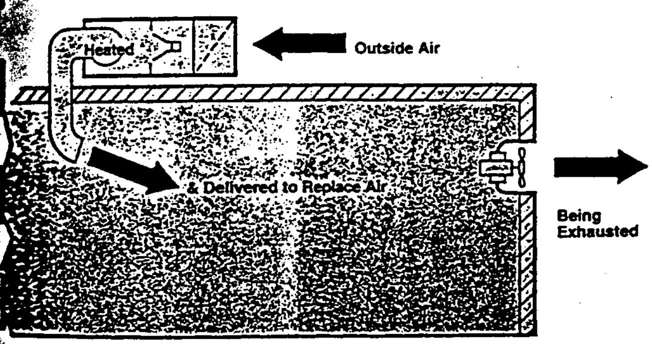
SBD DIRECT GAS-FIRED SERIES

The Need for Make-Up Air

Air exhausted from industrial or commercial buildings must be replaced. If provisions are not made for make-up air, there likely will be air starvation creating negative pressure within the building. This negative pressure, in turn, causes: outside air infiltration and cold drafts; down or back drafts in heating equipment flues, ventilators and stacks; reduced exhaust fan air volumes resulting in inadequate removal of contaminants; uncomfortable, and in many instances, unhealthy working conditions; and other problems.

The Source of Make-Up Air

With most applications requiring exhaust air provisions, replacement air must enter buildings either by infiltration through openings such as doors or windows, or supplied by a make-up air system. Infiltrated air is unheated, draft ridden and unfiltered resulting in an uncomfortable, uneven, and often unclean environment. A controlled source of make-up air eliminates the many problems of infiltration.



Make-Up Air

The SBD Direct Gas-Fired Systems

The SBD series of direct gas-fired make-up air systems was designed to furnish fresh, clean and heated air from a controlled source by the most fuel efficient and cost effect means. The SBD systems employ a method of supplying heated air into a building by passing fresh air directly over a gas flame in the air stream. The burner utilizes the kinetic energy of the air flow to complete combustion with the products of combustion well within code prescribed safety limits. The direct gas-fired burner, depicted in Figure 1, consists of drilled port cast iron pipe and two perforated stainless steel combustion baffles. The arrangement and shape of the air holes in the baffles provide the injection of proper combustion air at all rates of firing over a wide turndown range of up to :1. Since all the heat of the fuel goes into the air stream being heated, the direct gas-fired unit has 100% combustion efficiency and 92% overall thermal efficiency (with 8% of the total heat lost in the latent heat of water formed in combustion).

HOW CAN YOU RECOGNIZE THE NEED FOR MAKE-UP AIR?

Symptoms:

Back drafts and frequent pilot outages on natural draft heating equipment

Doors difficult to open

Exhaust fans not exhausting air

Cause:

Negative inside pressure from too little air replacing the air being exhausted

Symptoms:

Heaters not heating buildings

Cold drafts

Dust and dirt being drawn into building

Cause:

Untreated outside air infiltrated into building because of negative inside pressure

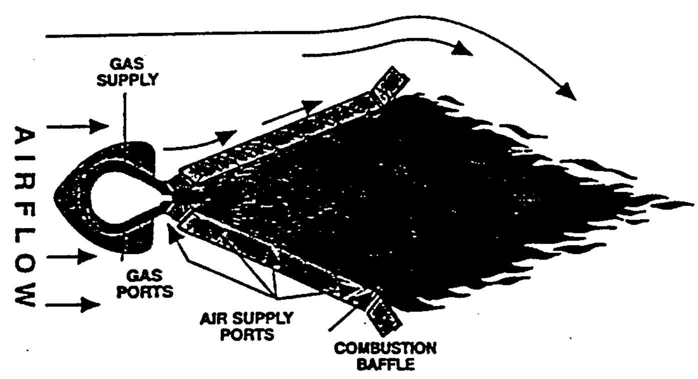
Symptoms:

Employees develop nausea and headaches

Cause:

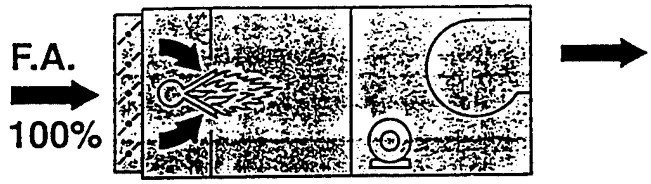
Build-up of inside contaminants due to inadequate ventilation

Figure 1



Direct Fired Line Burner

SBD — 100% FRESH AIR APPLICATIONS



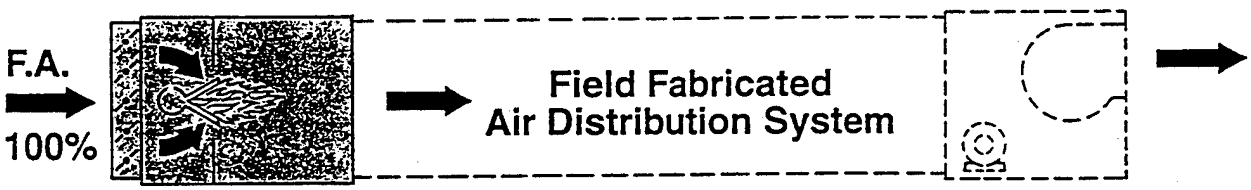
The basic SBD system is designed to introduce heated 100% outside air into a building to replace that amount of air which is exhausted. It is often desirable to bring in an excess of make-up air over that exhausted to insure a positive pressure in the area. This eliminates the many problems of negative pressure.

Normally the exhaust system is interlocked with the SBD make-up air system so that the units are in operation at the same time.

During operation of the SBD, air flow is continuous with discharge of air temperature regulated by modulating controls. The air temperature controls can either be non-electric modulating gas valves, modulating gas butterfly valves or electronic gas flame modulation. Each of these control systems allow the burner to operate at any point on its turndown range to provide a constant heater air discharge temperature.

The SBD system, in addition to its primary function as a make-up air heater, can also serve as a space heater. In many industrial and commercial applications it is practical and economically sound to use a single source of space heat and make-up air. In these instances, over-riding space air temperature controls are added to the basic discharge air temperature control system.

SBDF — DUCT FURNACE



The SBDF system consists of the basic SBD direct gas-fired burner section without a blower section. The burner section is applied as a duct furnace in field-fabricated ventilation systems.

All control and gas manifold options listed for the SBD systems are available with the SBDF direct gas-fired duct furnaces. Such accessories as filters, dampers and intake hoods can also be furnished with the furnaces.

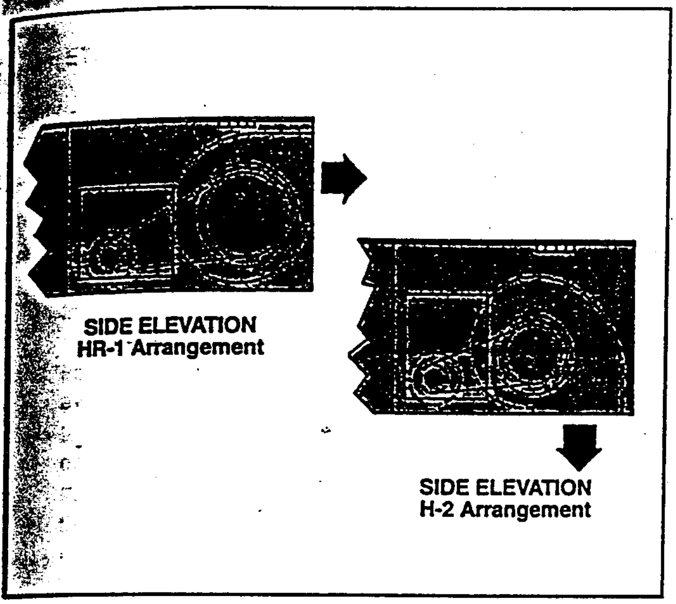
To avoid stratifications of the heated make-up air, the SBDF duct furnace should be located on the suction side of the blower to take advantage of the mixing effect of the fans.

While the performance data of the SBDF duct furnace is the same as that listed for the SBD and SBDR systems, a smaller size duct furnace may often be used with a field-fabricated ventilation application. The burner section size is no longer predicated on the physical size of the SBD blower section. Consult your local Hastings sales representative for selection and dimensional information.

Standard Equipment

General:

Either of two horizontal blower arrangements are available as standard: HR-1, horizontal discharge and HR-2, down discharge as illustrated below.



Blower:

Centrifugal forward curved, double width, double inlet, class 1 fan(s) with solid turned ground shaft and self-aligning, permanently lubricated ball bearings. All blower wheels are statically and dynamically balanced.

Blower housings, bearings and adjustable motor base are mounted on a reinforced frame to insure rigidity and quiet operation. Adjustable drives are standard through 10 HP, fixed drives with 15 HP and larger motors. V-belt drives are sized for 135% of motor horsepower.

Fan motors and drives are mounted within the blower cabinet. This affords motor protection and eliminates the operation hazard of V-belt drives external to the unit.

Cabinet:

Bolted construction of aluminized steel; SB-112 and SB-115 of 16 gauge, all other models with 14 gauge. Access panels are provided to allow easy access to motors, drives and filters (if ordered). Outside surface is primed with zinc-chromate and finished with a coat of enamel.

Motor:

T-frame, open drip-proof, 1800 RPM prelubricated ball bearing type for all standard voltages.

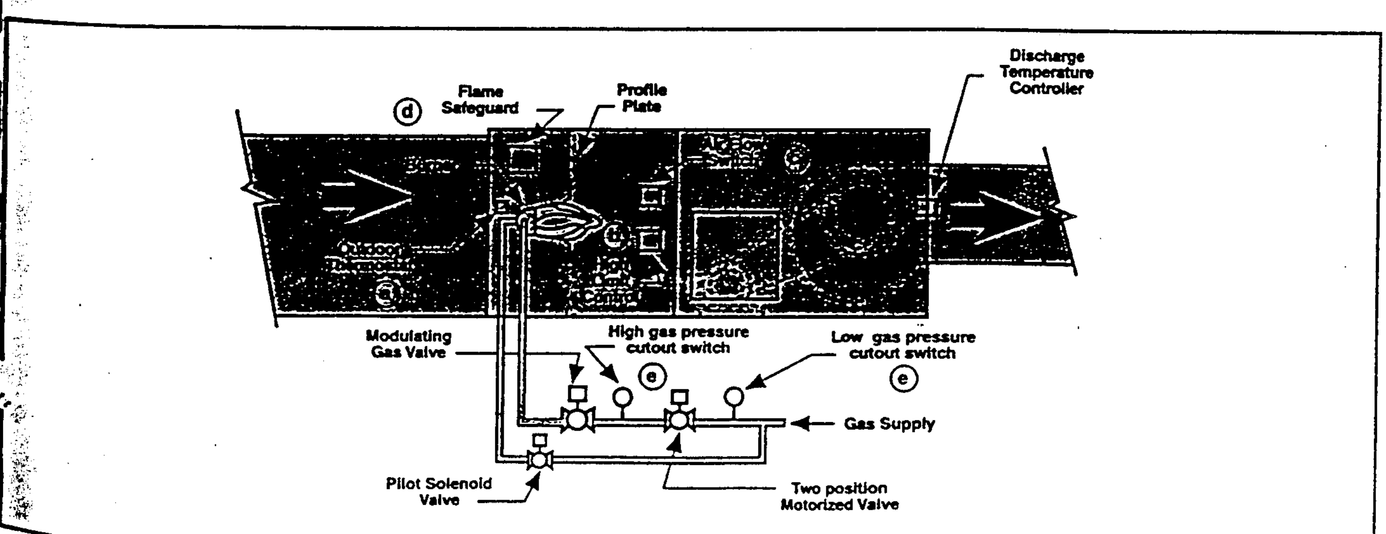
Burner:

Direct gas-fired line burner with spark ignited intermittent pilot for natural gas at inlet pressures from 8 oz. through 1 PSIG with up to 25:1 turndown ratio.

Gas and Electric Controls:

- Main gas hand shut-off valve.
- Main and pilot gas pressure regulators.
- Pilot controls.
- Electric safety shut-off valve.
- Self-contained gas modulating valve for units with burner capacity of 500 MBH or less.
- Motorized modulating gas valve with temperature controller for units with burner capacity above 500 MBH.
- Electronic flame safeguard system.
- High temperature limit switch.
- Airflow switch.
- Ignition transformer.
- Automatic mild weather burner lockout.
- Motor starter.
- Control transformer.
- NEMA 1 control box.
- Remote control station with system switches and indicating lights.

SAFETY AND LIMIT CONTROLS OF SBD SYSTEMS



Options and Accessories

General:

Horizontal unit blower arrangement — horizontal up flow (HR-3) available.

Vertical unit blower arrangement — three Vertical Up and three Vertical Down as illustrated below.

ETL Label Available

Components:

Weatherproof unit — for outdoor installations including hinged and latched weatherproof control enclosure.

Insulated blower section — 1 inch, 2 pound density, mat face fiberglass insulation up to leaving air side of burner profile plates.

Insulated burner section — available on all units.

Stormproof weatherhood — with birdscreen. Installed on air intake of horizontal, HR-1 and HR-2, weatherproof units. Not available with optional vertical blower arrangements.

Birdscreen — for installation on the air intake of units with optional vertical blower arrangements.

Filter section — with "V" or "Z" frames for mounting 2 inch throwaway, cleanable or extended surface filters. A clogged filter switch with indicating light is available as an optional item. Filter section can also be insulated. Available for return air also.

Shut-off dampers — complete with two position damper motor and end switch. Discharge air damper suggested for indoor installations. Low leakage dampers are also available.

Discharge air louvers — adjustable horizontal or vertical bladed louvers are available for mounting on the blower outlet. These louvers can be combined for double deflection air control.

Service platform — with guardrail per OSHA standard. Service platforms are available for indoor horizontal units only.

Vibration isolators — either "rubber-in-shear" or spring type for floor or roof mounting, or indoor suspension. Not compatible with curb mounted units. Vibration isolators are shipped unmounted. Internal fan/motor isolation is also available.

Extended grease lines — for remote greasing of fan bearings from the control side of unit.

Burner — 50 to 1 turndown available.

Variable pitch sheave — for motors 15 HP and larger. Variable pitch sheaves are standard for motors 10 HP and smaller.

Motors:

Totally enclosed, two speed, explosion proof, automotive duty or chemical duty motors available on all units.

Roof Curbs:

Adapter frames and roof curbs available for horizontal units. Roof curbs are shipped knocked down. Discharge duct adapters are standard on HR-2 units with discharge dampers.

Miscellaneous:

Motor and controls can be mounted on opposite side. Matching cooling coil, heat reclaim coil, electric heater and evaporative cooling sections available for all models.

Electric Controls:

Fused disconnect switch — dead front fused disconnect switch or circuit breaker mounted in cover of main control box.

Blocked intake switch — complete with indicating light. Warning light is turned on in case of insufficient air delivery for proper combustion.

Low outlet temperature shut-off — Shuts off blower, after time delay, if unit delivers cold air due to burner failure.

Pre-purge cycle — Blower purges unit cabinet for selected time, 7 second minimum, before burner turns on. Not normally required unless unit can fill with combustible vapors between cycles. This item furnished as standard with FM and IRI controls.

Circuit analyzer — provides a network of indicating lights to check circuit continuity. Simplifies identification of malfunctioning control.

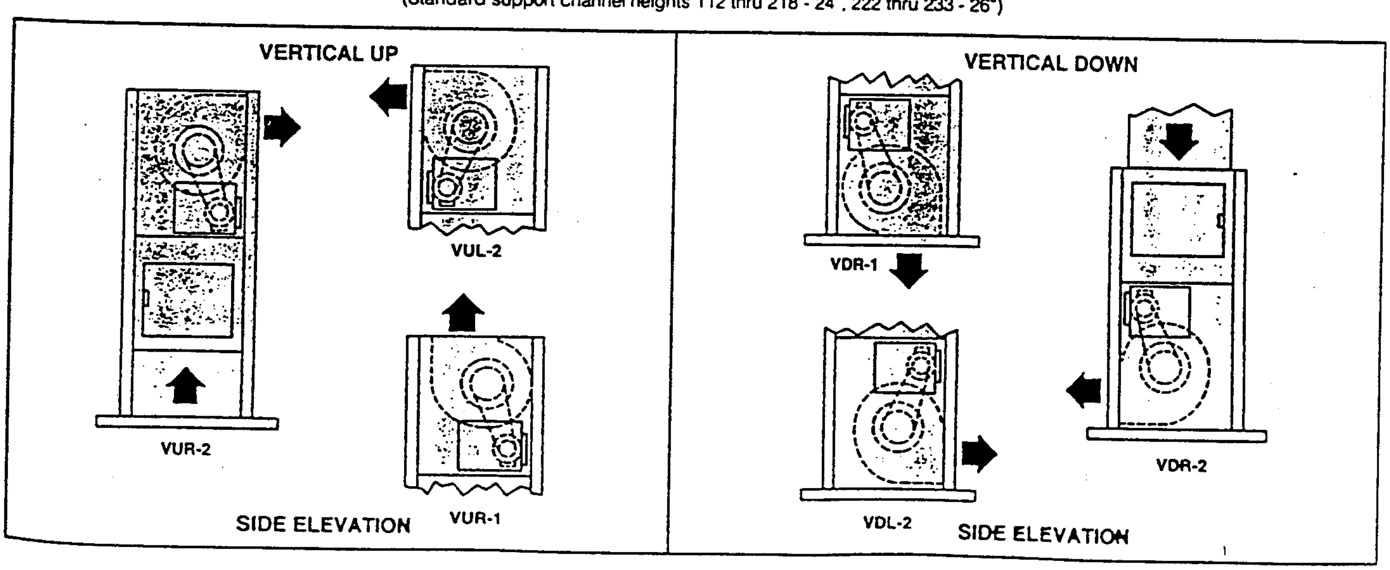
Ultra-violet flame sensor — ultra-violet flame sensing is used in place of standard flame rod system. Desirable for applications where excessive condensation of moisture is encountered.

Night setback thermostat — cycles blower-burner on basis of space temperature. Night control can either be energized manually or by a time clock.

Note: Burner and Gas Control options on page 6.

VERTICAL UNIT BLOWER DISCHARGE ARRANGEMENTS

(All sections and components are supported by special base frame and vertical support channels)
*(Standard support channel heights 112 thru 218 - 24", 222 thru 233 - 26")



Options and Accessories

Burners:

Propane firing — primary fuel — a propane line burner is furished with this option.

ropane firing — standby fuel — a three-way hand valve is actory mounted. The pilot, however, stays on natural gas. his option is not designed for use with mixed propane-air gas with properties similar to natural gas. A standard burner will be furnished. Contact your Hastings sales representative for pecial applications with two speed motors being used with ual-fuel. Not available with selectra modulation systems.

Gas Controls:

M or IRI approved controls — additional gas manifold conrols are furnished to meet insurance authority requirements.

High gas pressure regulator — a high gas pressure regulator s substituted for the standard regulator with inlet gas presures over 1 PSIG.

Motorized modulating gas valve — with temperature controller available for units, 500 MBH or less, having self-contained gas valve as standard.

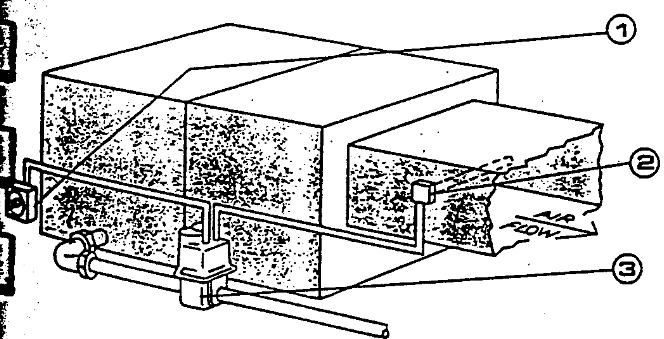
Modulating room thermostat — heating is controlled by the modulating room thermostat. If discharge air temperature falls below the setting of the modulating low limit the room thermostat is over-ridden and heating output is increased until the modulating low limit is satisfied. Likewise, if discharge air temperature rises above the setting of the modulating high limit controller, the room thermostat is again over-ridden and heating output is decreased until the discharge air temperature falls below the set point of the high limit control.

High or low gas pressure switch — manual reset type with adjustable set point. Offered to meet special code requirements or where added protection is desired. These gas pressure switches are part of the package furnished with FM and IRI options.

Selectra modulation system — a solid state electronic temperature control system is available to replace the standard self-contained or electric motorized gas valve controls. Both the Series 14 and Series 44 Selectra systems are described below.

SELECTRA MODULATIONS SYSTEMS

SERIES 14



electra Series 14 electronic gas flame modulation system atures precise discharge air temperature control, decreasng variations or temperature "swings."

All components are pre-calibrated — not requiring matching sets.

Temperature selector is mounted in any convenient location or the dial can be incorporated in the remote control panel. discharge air temperature can be quickly and easily reset to meet changing requirements.

Thermistor in the discharge air monitor continuously senses outlet air temperature and transmits an instantaneous signal, through a solid state amplifier, to the modulator/regulator gas valve.

Immediately responding to the signal from the sensor, the modulator/regulator valve changes gas pressure to control burner input and maintain discharge air temperature at a constant level.

Options include —

Over-riding room thermostat — two position control of space temperature.

Indoor-outdoor reset — raises discharge air temperature one degree for every eight degree drop in outdoor temperature.

SERIES 44

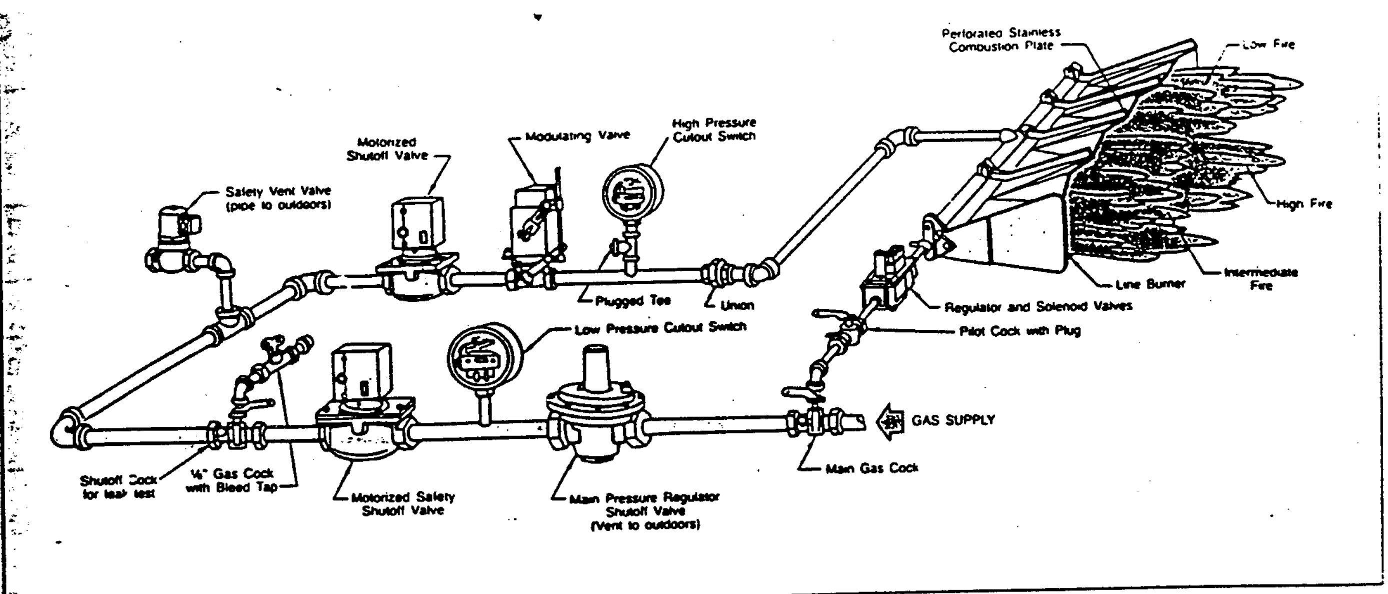
he Selectra Series 44 system converts a single purpose ake-up air unit into one with dual operating characteristics, ating the ventilating air while controlling the space temperare.

eries 44 features electronic modulating space temperature ensing and control while, at the same time, preventing objecnable discharge air temperature extremes.

The basic system includes a solid state amplifier/control center, a discharge air monitor with high and low temperature thermistors, a modulator/regulator valve, and a space temperature sensor with remote temperature selector.

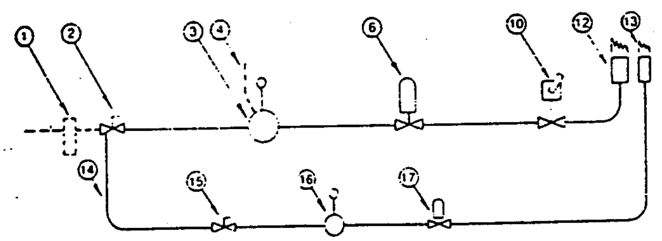
As an alternative, a selectrastat and thermistor sensing remote space temperature is also available.

TYPICAL GAS MANIFOLD AND BURNER—with Insurance Authority Controls

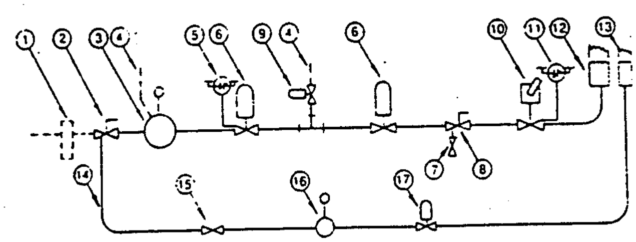


SCHEMATIC PIPING DIAGRAMS

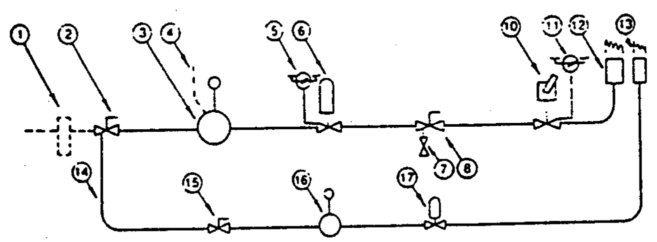
Standard Manifold — Any input without FM or IRI Approval



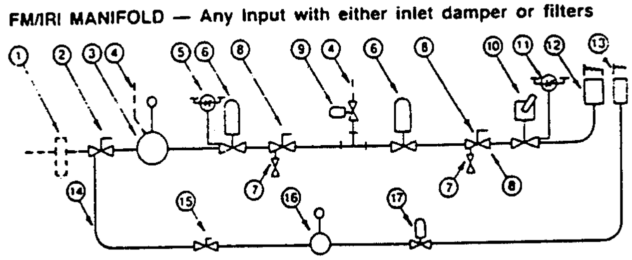
IRI — Over 1,000,000 Input



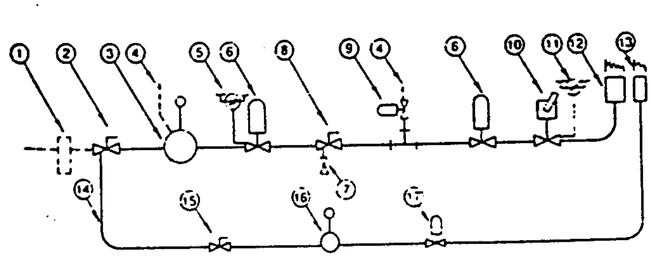
FM MANIFOLD — Any Input without inlet dampers or filters
IRI MANIFOLD — Under 1,000,000 Input



FM/IRI MANIFOLD — Any Input with either inlet damper or filters



FM MANIFOLD — Any Input with either inlet damper or filters



ITEM	DESCRIPTION	Factory Furnished & Installed	Furnished by Factory, Installed by Others	Furnished & Installed by Others
1	Drip Leg			X
2	Main Gas Hand Shut-off Valve	X		
3	Main Gas Pressure Regulator	X		
4	Vent Line Thru Roof to Outside Atmosphere			X
5	Low Gas Pressure Switch	X		
6	Safety Shut-off Valve	X		
7	Leak Test Petcock w/Plugged Test Connection	X		
8	Manual Leak Test Hand Valve	X		
9	Vent Valve (Normally Open)	X		
10	Modulating Valve	X		
11	High Gas Pressure Switch	X		
12	Main Gas Burner	X		
13	Pilot Gas Burner	X		
14	Pilot Gas Supply Line	X		
15	Pilot Gas Hand Valve	X		
16	Pilot Pressure Regulator	X		
17	Pilot Gas Solenoid Valve	X		

SBD DIRECT GAS-FIRED SERIES

SBD SERIES SELECTION TABLE

Model	Air Delivery – SCFM	Outlet Velocity – FPM	Approx. Shipping Weight Lbs.	MBH Input – Air Temperature Rise									Motor Horsepower – Total Static Pressure (Refer to Notes Below)						
				40	50	60	70	80	90	100	110	120	¾"	1"	1¼"	1½"	1¾"	2"	2½"
SBD 112	2000	1307	480	94	117	141	164	188	211	235	258	282	¾	¾	1	1	NA	NA	NA
	3000	1961	490	141	176	211	247	282	317	352	387	423	1½	1½	1½	2	NA	NA	NA
SBD 115	4000	1754	700	188	235	282	329	376	423	470	517	563	1½	1½	2	2	3	3	NA
	5000	2193	700	235	293	352	411	470	528	587	646	704	2	2	3	3	3	5	5
	6000	2632	725	282	352	423	493	563	634	704	775	845	3	3	5	5	5	5	5
	7000	3070	735	329	411	493	575	657	740	822	904	986	5	5	5	5	7½	7½	7½
	8000	3509	735	376	470	563	657	751	845	939	1033	1127	5	7½	7½	7½	7½	7½	NA
SBD 215	6000	1202	1200	282	352	423	493	563	634	704	775	845	1½	3	3	5	5	5	7½
	7000	1403	1200	329	411	493	575	657	740	822	904	986	2	3	3	5	5	5	7½
	8000	1603	1200	376	470	563	657	751	845	939	1033	1127	3	3	5	5	5	7½	7½
	9000	1804	1200	423	528	634	740	845	951	1057	1162	1268	3	5	5	5	7½	7½	10
	10000	2004	1225	470	587	704	822	939	1057	1174	1291	1409	3	5	5	7½	7½	7½	10
	12000	2405	1230	563	704	845	986	1127	1268	1409	1550	1690	5	7½	7½	7½	7½	10	10
	14000	2806	1230	657	822	986	1150	1315	1479	1643	1808	1972	71/2	71/2	10	10	10	10	NA
	16000	3205	1275	751	939	1127	1315	1503	1690	1878	2066	2254	10	10	10	10	NA	NA	NA
SBD 218	10000	1745	1720	470	587	704	822	939	1057	1174	1291	1409	3	3	5	5	5	NA	NA
	12000	2094	1730	563	704	845	986	1127	1268	1409	1550	1690	5	5	5	7½	7½	7½	10
	14000	2443	1730	657	822	986	1150	1315	1479	1643	1808	1972	5	7½	7½	7½	7½	10	10
	16000	2792	1775	751	939	1127	1315	1503	1690	1878	2066	2254	7½	7½	10	10	10	15	15
	18000	3141	1775	845	1057	1268	1479	1690	1902	2113	2324	2536	10	10	15	15	15	15	15
	20000	3490	1800	939	1174	1409	1643	1878	2113	2348	2583	2817	15	15	15	15	15	20	20
	22000	3839	1800	1033	1291	1550	1808	2066	2324	2583	2841	3099	15	20	20	20	20	20	NA
SBD 222	18000	1929	2730	845	1057	1268	1479	1690	1902	2113	2324	2536	7½	7½	10	10	15	15	15
	20000	2144	2730	939	1174	1409	1643	1878	2113	2348	2583	2817	7½	10	10	15	15	15	20
	22000	2358	2780	1033	1291	1550	1808	2066	2324	2583	2841	3099	10	15	15	15	15	20	20
	24000	2573	2800	1127	1409	1690	1972	2254	2536	2817	3099	3381	15	15	15	15	20	20	25
	26000	2787	2800	1221	1526	1831	2137	2442	2747	3052	3357	3663	15	15	20	20	20	25	25
	28000	3001	2850	1315	1643	1972	2301	2630	2958	3287	3616	3944	20	20	20	25	25	25	NA
	30000	3215	2875	1409	1761	2113	2465	2817	3170	3522	3874	4226	20	25	25	25	NA	NA	NA
	32000	3430	2900	1503	1878	2254	2630	3005	3381	3757	4132	4508	25	25	NA	NA	NA	NA	NA
SBD 227	28000	1713	3600	1315	1643	1972	2301	2630	2958	3287	3616	3944	10	10	15	15	15	20	25
	30000	1835	3620	1409	1761	2113	2465	2817	3170	3522	3874	4226	10	15	15	15	20	20	25
	35000	2141	3685	1643	2054	2465	2876	3287	3698	4109	4520	4930	15	15	20	20	25	25	30
	40000	2446	3685	1878	2348	2817	3287	3757	4226	4696	5165	5635	20	20	25	25	25	30	40
	45000	2752	3720	2113	2641	3170	3698	4226	4754	5283	5811	6339	25	25	30	30	30	40	40
	50000	3058	3810	2348	2935	3522	4109	4696	5283	5870	6457	7043	30	40	40	40	40	50	50
	55000	3354	3870	2583	3228	3874	4520	5165	5811	6457	7102	7748	40	40	50	50	50	50	NA
	60000	3670	3920	2817	3522	4226	4930	5635	6339	7043	7748	8452	50	50	50	NA	NA	NA	NA

notes at bottom of Selection Table on opposite page.

SBD SERIES COLLECTION TABLE

Model	Air Delivery – SCFM	Outlet Velocity – FPM	Approx. Shipping Weight Lbs.	MBH Input / Air Temperature Rise 40	50	60	70	80	90	100	110	120	Motor Horsepower / Total Static Pressure (Refer to Notes Below) ¾"	1"	1¼"	1½"	1¾"	2"	2½"
SBD 233	40000	1888	5100	1878	2348	2817	3287	3757	4226	4696	5165	5635	15	15	20	20	20	25	30
	45000	2124	5100	2113	2641	3170	3698	4226	4754	5283	5811	6339	15	20	20	25	25	30	40
	50000	2360	5140	2348	2935	3522	4109	4696	5283	5870	6457	7043	20	25	25	30	30	40	40
	55000	2596	5200	2583	3228	3874	4520	5165	5811	6457	7102	7748	25	30	30	40	40	40	50
	60000	2832	5235	2817	3522	4226	49/30	5635	6339	7043	7748	8452	30	40	40	40	40	50	50
	65000	3067	5330	3052	3815	4578	5341	6104	6867	7630	8393	9157	40	40	40	50	50	50	60
	70000	3303	5330	3287	4109	4930	5752	6574	7396	8217	9039	9861	40	50	50	50	60	60	CHO
	75000	3539	5380	3522	4402	5283	6163	7043	7924	8804	9685	10565	50	60	60	60	CHO	CHO	NA

NOTES:
1. Use Total Static Pressure column that will overcome total system resistance. Approximate pressure drop for component and accessory items; burner 1/2", filter (dirty) 1/4", intake hood 1/8", birdscreen 1/8", discharge louver 1/8". Damper resistance may be ignored.
2. Refer to fan curves in bulletin SB-1 for blower RPM and brake horsepower.
3. NA – Not Available, CHO – Contact Home Office.
4. 50 to 1 Turndown available – CHO

Selection Procedure:

1. Choose either SBD system for 100% outside air or SBDR system for return air capability.
2. Determine required model size from selection table with desired SCFM of make-up air and MBH input or air temperature rise in °F. Please note that:

   $$\text{Air temp rise} = \frac{.92 \times \text{MBH Input}}{1.08 \times \text{SCFM}}$$

3. For model size selected, read required motor horsepower to overcome total static pressure resistance. Approximate static pressure losses for component and accessory items are: burner ½", filter (dirty) ¼", intake hood ⅛", discharge louver ⅛". Damper resistance may be ignored.

   Also specify type of gas and gas pressure, mounting location, blower discharge arrangement and motor electric characteristics.

Example:

Select a direct gas-fired heating system to heat 18,000 SCFM of 100% outside air with an air temperature rise of 90°F. Total static pressure required is 1.75" w.c. Unit to be rooftop mounted with down discharge through roof, and furnished with throw-away filters and intake hood. Fuel is natural gas at 1 PSIG inlet pressure.

1. SBD system is chosen for 100% outside air.
2. At 18,000 SCFM and 90°F temperature rise, select model size 218. Heat input will be 1,902 MBH.
3. For size 218 with 1.75" w.c. total static pressure, selection table indicates that a 15 HP motor is required.

Selection is thus complete:

Model SBD-218-18-1902 with 15 HP motor. Unit to be natural gas fired with 1 PSIG pressure, rooftop mounted, weatherproofed, HR-2 blower arrangement, 230/60/3 power, and furnished with 2" throwaway filters and intake hood.

MODEL DESIGNATION

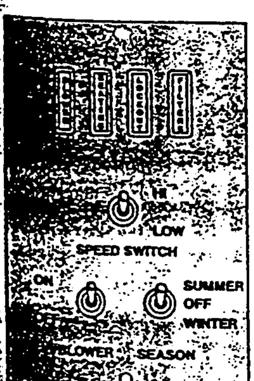
SBD xxx -x- xxx

SB Blower Model: 112 thru 233

Air Volume: SCFM/1000

Heating Capacity: MBH Input

REMOTE CONTROL STATION



Remote control station with switches and indicating lights is standard with SBD and SBDF direct gas-fired make-up air systems. The panel shown is typical for SBD two speed unit. Front panel and wiring will change according to items furnished.

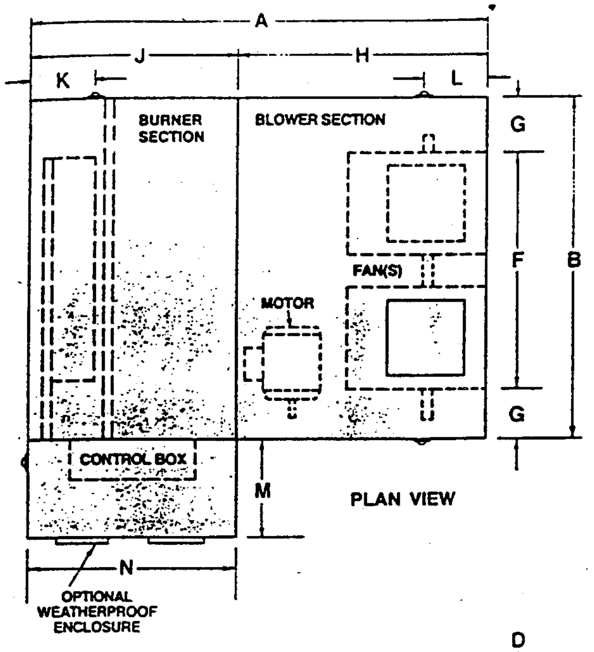
Standard remote control station is 8 inches high, 5 inches wide and 3-1/2 inches deep with stainless steel panel. A flush mounted panel is available as an optional item.

GAS MANIFOLD SIZE

Based on standard 10" inlet gas pressure

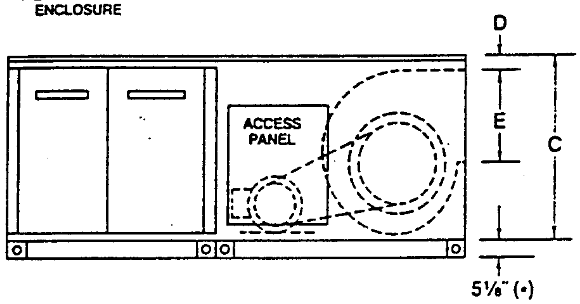
Manifold Size NPT	Maximum MBH Input – Natural Gas: Standard Modulation	Standard W/RA or FM	Selectra Modulation	Selectra W/RA or FM
1	1150	940	1130	940
1¼	1540	1340	1410	1255
1½	2840	2270	2170	1860
2	4640	3830	3420	3060
2½	6820	5500	5200	4470
3	9050	7000	6900	5840

SBD — HORIZONTAL MODEL BASE UNIT

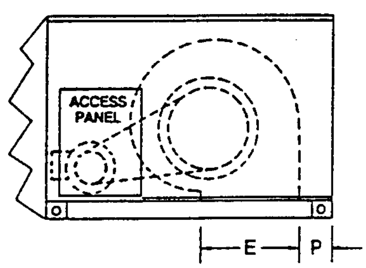


SBD MODELS														
Size	A	B	C	D	E	F	G	H	J	K	L	M	N	P
112	76⅞	33	26½	2⅝	13½	16¼	8⅜	36⅞	40	12½	11	26	39¾	1⅛
115	83¾	40	35	2⅝	16⅝	19¾	10⅛	43¾	40	12½	13⅞	26	39¾	1⅛
215	88⅛	75⅛	35	2⅝	18¼	55⅜	9⅞	48⅛	40	12½	15⅛	26	39¾	1⅛
218	89⅛	79⅛	39	2⅝	18⅞	58⅜	10⅜	49⅛	40	12½	12⅝	26	39¾	1⅛
222	107⅛	96⅝	49	4	24¼	76⅛	10¼	67⅛	40	—	—	32	39¾	8
227	123	114⅜	58	5⅜	34⅜	88⅞	12¾	83	40	—	—	32	39¾	8
233	129⅛	141	67	4	34⅛	115	13	89⅛	40	—	—	32	39¾	8

All dimensions in inches.



SIDE ELEVATION
HR-1 Arrangement



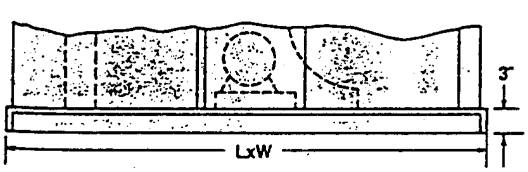
SIDE ELEVATION
HR-2 Arrangement

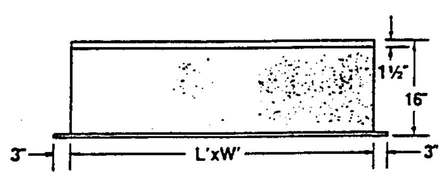
NOTES:

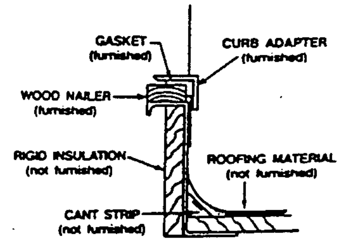
1. SBD-112 through SBD-218 have combination lifting and hanging lugs.
2. SBD-222, SBD-227 and SBD-233 have channel base frames with combination lifting-hanging lugs.

(*) Base channel on SBD-222, SBD-227 and SBD-233 only.

SBD — OPTIONAL ROOF CURB







Curb Adapter Frame ①

Model	112	115	215	218
L	82⅝	89⅜	93⅞	94⅞
W	34	41	76⅛	80⅛

All dimensions in inches.

① Channel frame for SBD 222, 227 and 233 mounts directly to roof curb.

Roof Curb

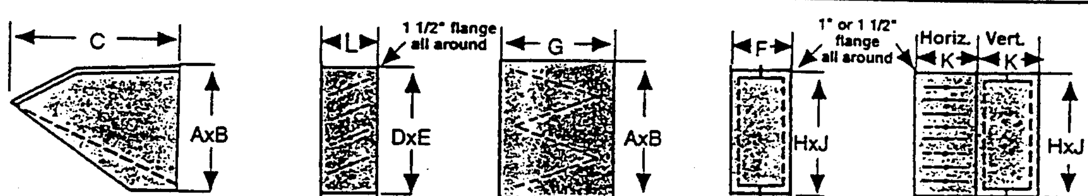
Model	112	115	215	218	222	227	223
L'	81⅛	87⅞	92⅜	93⅜	107⅛	123	129
W'	32½	39½	74⅝	78⅝	96⅝	114¼	141

NOTE: Duct adapter for HR-2 curb mounted unit is furnished as standard equipment when Hastings curbs are supplied.

EQUIPMENT SPECIFICATIONS

SECTION	DESCRIPTION	SB-122	SB-115	SB-215	SB-218	SB-222	SB-227	SB-23
BLOWER	Discharge Arrangement	* Horizontal Unit with Choice of HR-1 (Horizontal or HR-2 (Down)						
	Construction	Aluminized Steel Casing — Bolted Construction						
	Casing Gauge	16	16	14	14	14	14	14
	Outside Surface Finish	Primed with Zinc-Chromate. Finish Coat of Enamel						
	Type of Fans	Centrifugal, Forward Curved, DWDI, Class 1						
	Number of Fans	1	1	2	2	2	2	2
	Outlet Area (Sq. Ft.)	1.53	2.28	4.99	5.73	9.33	16.35	21.19
	Ball Bearings	Self Aligned and Prelubricated Pillow Block or Flange Mounted						
	Lubrication	Permanent Prelubrication			Means for Relubrication			
	Bearing Size (inches)	1	1 3/16	1 11/16	1 15/16	1 7/16	1 11/16	1 15/16
	Shaft Diameter (inches)	1	1 3/16	1 11/16	1 11/16	1 7/16	1 11/16	1 15/16
	Motor Location	Internal Mounting						
	Drives	Adjustable Standard thru 10HP; Fixed Standard above 10 HP, Adjustable Optional						
	General	Wheels Statically & Dynamically Balanced, Mounting on Separate Frame						
FILTER (OPTIONAL)	Arrangement	V-Bank						
	Casing Gauge	16	16	16	16	14	14	14
	Number of Filters	4	8	12	12	24	30 and 6	49
	Size (inches)	16x20x2	20x20x2	20x25x2	20x25x2	16x25x2 and 16x25x2	20x25x2	20x25x2

SBD – ACCESSORY ITEMS



Intake Hood with Birdscreen

Inlet Shut-off Damper

Filter Section

Discharge shut-off Damper

Double Deflection Discharge Louvers

SBD – ACCESSORY ITEMS												
SIZE	A	B	C	D	E	F	G	H	J	K	L	Filters – No. & Sizes
112	26 ½	33	35 ⅞	23 ⅜	29 ⅞	12	24 ¾	13 ½	16 ¼	4"	8 ⅝	4) 16 x 20 x 2
115	35	40	43 ¾	31 ⅞	36 ⅞	12	26	16 ⅝	19 ¾	4"	8 ⅝	8) 20 x 20 x 2
215	35	75 ⅛	43 ¾	31 ⅞	72	12	26	18 ¼	55 ⅜	4"	8 ⅝	12) 20 x 25 x 2
218	39	79 ⅛	47 ¼	35 ⅞	76	12	26	18 ⅞	58 ⅜	4"	8 ⅝	12) 20 x 25 x 2
222	49	96 ⅝	56 ⅜	45 ⅞	93 ⅞	12	30	24 ¼	76	4"	8 ⅝	24) 16 x 25 x 2
227	58	114 ⅜	59 ⅜	54 ⅞	111 ¼	12	30 ⅞	34 ¼	89	4"	8 ⅝	30) 20 x 25 x 2 & 6) 16 x 25 x 2
233	67	141	58 ⅞	63 ⅞	137 ⅞	12	30 ¾	34 ¼	115	4"	8 ⅝	49) 20 x 25 x 2

All Dimensions in inches

Hastings

SBD DIRECT GAS-FIRED SERIES

Engineers Specifications

Furnish and install the following Hastings direct gas-fired make-up air system.

Blower Section:

A. Blower wheels shall be statically and dynamically balanced forwardly curved, double width, double inlet, class 1.

B. Blower wheels shall be mounted on solid turned ground shaft with keyway for driven shaft.

C. Bearings shall be ball bearing, self-aligning, permanently or pre-lubricated, pillow-block or flange mounted.

D. Blower housings, bearings and adjustable motor base shall be mounted on a reinforced frame to insure rigidity and quiet operation.

E. The driver and driven sheaves shall be of the keyed hub type. The driven sheave shall be of a fixed pitch diameter and the driver sheave shall be of a variable pitch diameter through 10 HP and fixed pitch above 10 HP. V-belt drives shall be sized for 135% of motor horsepower.

F. Cabinet shall be constructed of high quality (16) (14) gauge aluminized steel to insure long rust-free life.

G. Access panels shall be provided to allow easy access to motors and filters (if ordered).

H. Outside surface of cabinet shall be primed and finished with a coat of enamel.

Burner Section:

A. The burner shall be a direct gas-fired line burner suitable for complete combustion of natural gas, propane or propane-air mixture, and having a turndown ratio of up to 25:1 available.

B. Burner combustion must be clean and odorless. Combustion efficiency must limit the products of combustion to a maximum of 5 ppm carbon monoxide and a maximum of 0.5 ppm nitrogen dioxide.

C. The burner shall have stainless steel combustion baffles, non-clogging gas ports, spark-ignited intermittent pilot and flame safeguard system.

D. Observation port shall be provided in burner cabinet.

E. Profile plates to control proper air velocity across the burner shall be factory installed, adjusted during an actual firing test and locked in place before shipment.

Motor:

A T-frame, ODP, 1800 RPM prelubricated ball bearing type motor shall be furnished for voltage as scheduled.

Gas and Electric Controls:

The following controls shall be furnished with the direct gas-fired make-up air system:

- Main gas hand shut-off valve.
- Main and pilot gas pressure regulators.
- Pilot controls.
- Electric safety shut-off valve.
- Self-contained gas modulating valve for units with burner capacity of 500 MBH or less.
- Motorized modulating gas valve with temperature controller for units with burner capacity above 500 MBH.
- Electronic flame safeguard system.
- High temperature limit switch.
- Airflow switch.
- Ignition transformer.
- Automatic mild weather burner lockout.
- Motor starter.
- Control transformer.
- NEMA 1 control box.
- Remote control station with system switches and indicating lights.

Assembly:

The system shall be factory assembled and wired with the exception of controls that are remote to the unit.

Options and Accessories:

The following items are to be furnished (Insert desired items from pages 5 and 6 of this bulletin.)

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